MARYLAND GEOLOGICAL SURVEY

VOLUME FOUR

MARYLAND

GEOLOGICAL SURVEY

VOLUME FOUR

BALTIMORE
THE JOHNS HOPKINS PRESS
1902

The Lord Baltimore Press
THE FRIEDENWALD COMPANY
BALTIMORE, MD., U. S. A.

COMMISSION

JOHN WALTER SMITH, ... PRESIDENT.
GOVERNOR OF MARYLAND.

JOSHUA W. HERING, ...
COMPTROLLER OF MARYLAND.

IRA REMSEN, ... EXECUTIVE OFFICER.
PRESIDENT OF THE JOHNS HOPKINS UNIVERSITY.

R. W. SILVESTER, ... SECRETARY.
PRESIDENT OF THE MARYLAND AGRICULTURAL COLLEGE.

SCIENTIFIC STAFF

WM. BULLOCK CLARK, ...	STATE GEOLOGIST.
SUPERINTENDENT OF THE SURVEY.	
EDWARD B. MATHEWS, . .	ASSISTANT STATE GEOLOGIST.
CHARLES S. PROSSER, ...	GEOLOGIST.
GEORGE B. SHATTUCK, ...	GEOLOGIST.
GEORGE C. MARTIN, ...	GEOLOGIST.
HARRY FIELDING REID, . .	CHIEF OF HIGHWAY DIVISION.
A. N. JOHNSON, ...	HIGHWAY ENGINEER.
J. MORRISON HARRIS, ...	ASSISTANT.
H. H. HINDSHAW, ...	ASSISTANT.
F. H. SCHLOER, ...	MACHINIST.
MYRA ALE, ...	SECRETARY.

LETTER OF TRANSMITTAL.

To His Excellency John Walter Smith,

Governor of Maryland and President of the Geological Survey Commission.

Sir:—I have the honor to present herewith the fourth volume of the general reports of the Maryland Geological Survey. The information contained in it is largely of economic interest and will, I feel confident, add much to the knowledge of the material resources of the State. I am,

Very respectfully,

Wm. Bullock Clark,

State Geologist.

Johns Hopkins University,
Baltimore, *April, 1902.*

CONTENTS

ILLUSTRATIONS.

PREFACE

The present volume, constituting the fourth of the general reports of the Survey, contains, first, an account of the results reached concerning the various changes that have occurred in Western Maryland during geologic time; second, additional information regarding the highways of the State and the efforts which have been made to improve their condition; and third, an exhaustive discussion of the extensive clay deposits of Maryland.

Paleozoic Appalachia or the History of Maryland during Paleozoic Time, by Bailey Willis, constitutes Part I of the volume, and is a contribution to the study of the physical changes which have taken place over a wide area of which Maryland is a part. Mr. Willis, who was for several years Geological Assistant to the Director of the U. S. Geological Survey, and who is now in charge of the geological mapping in that bureau, has had special advantages to fit him to write such a paper as this. His wide experience in geologic work throughout the Appalachian region and his lucid style make this paper a valuable summary of the geological history of Appalachian Maryland as recorded in the mechanical characteristics of the rocks. The report, after an explanation of the processes which have wrought the changes, gives an account of the growth and wasting of several mountain systems, the expansion of plains of continental extent and their submergence beneath widening seas, the construction and migration of co-extensive coastal plains, the upfolding and dislocation of sedimentary strata from two to six miles thick in a zone a hundred miles wide and fifteen hundred miles long, and the withdrawal of the sea from the province over which it had extended during many million years. Such a history represents broad generalizations which cannot fail to be of interest to every thoughtful citizen of the State.

The Second Report on the Highways of Maryland, by Harry Fielding Reid and A. N. Johnson, forms Part II of the volume. This treats of the operations of the Highway Division of the Survey during

1900 and 1901. The first report presented the conditions of the highways throughout the State and prepared the way for making the desired improvements. The present report, after a discussion of several changes in the testing of road materials devised in the laboratory of the Division and the results obtained in several hundred tests of paving-brick, cement and road materials, describes the work which has been carried on under the supervision of the Division. This portion of the report is of unusual interest in showing how much permanent improvement of the highways might be made by a proper use of the means now available without additional cost to the counties. This part closes with the report of the Baltimore County Roads Engineer, which was submitted to the Survey in accordance with the law. This report gives a detailed statement of the amount spent for labor and materials on each road and indicates that Baltimore County has taken a great step forward by employing a capable roads engineer.

The Report on the Clays of Maryland, by Heinrich Ries, the leading clay expert of this country, forms Part III of the volume. This report is divided into two parts. The *first* comprises an elaborate discussion of the properties of clays and the effects of the different chemical and physical elements of a clay and shows how their bad qualities can be offset by the addition of proper ingredients. Professor Ries, as the agent of the U. S. Geological Survey and as a leading expert on clays, is particularly well qualified to speak of these properties and of the proper methods for testing the actual value of clays. The suggestions contained in this portion of the report and the systematic statement of the leading facts regarding the technology of clay-working will doubtless prove of much value to the clay-workers. The *second* part of the report represents the knowledge gained from a study of the principal deposits of clay found within the confines of the State and the numerous tests of samples collected by Professor Ries and the members of the Survey from the clay banks from all parts of Maryland. This report, with its maps showing the locations of the different areas for clay and their relation to transportation facilities, should attract the attention of business men to the wealth of the State in valuable clays and should draw to the State large

operators who will develop extensive industries which should give employment to many of our citizens.

The illustrations contained within this volume have been secured from many sources. Many of them have been made by the writers of the several reports or members of the Survey, while many of the manufacturers of brick-making machinery have aided in generously putting at the disposal of the Survey original drawings and cuts which have served as the basis for the illustrations used in that portion of Professor Ries' report dealing with the methods of working clay. Among those who have rendered such assistance are:

The American Clay-working Machinery Co., Bucyrus, Ohio; Buffalo Dental Mfg. Co., Buffalo, N. Y.; Chambers Bros. Co., Philadelphia, Pa., Chisholm, Boyd & White Co., Chicago, Ill.; H. Haigh, Catskill, N. Y.; Henry Martin Brick Machine Mfg. Co. Inc., Lancaster, Pa.; Illinois Supply and Construction Co., St. Louis, Mo.; John Johnson & Co., New York City; Raymond Bros. Impact Pulverizer Co., Chicago, Ill.; Simpson Mfg. Co., Chicago, Ill.; Steadman Foundry and Machine Works, Aurora, Ind.; Sturtevant Mill Co., Boston, Mass.; and Toplin, Rice & Co., Akron, Ohio. The Survey is likewise indebted to Dr. F. J. H. Merrill, Director of the New York State Museum, for the loan of plates from the reports of the Museum. The plates illustrating Part III represent Maryland works and Maryland deposits in every instance.

The Survey is especially indebted to the Director of the U. S. Geological Survey, Hon. Charles D. Walcott, who has permitted the use of several illustrations from the publications of that bureau, and has actively coöperated with the local organization in the gathering of the statistical information concerning the clay-working industries of the State since the organization of the present Survey.

There has likewise been active coöperation with the U. S. Department of Agriculture in the perfecting of suitable methods for determining the value of road materials, and with the County Commissioners and Road Supervisors of the several counties in the improvement of the roads of their respective districts.

PART I

THE APPALACHIAN REGION

PALEOZOIC APPALACHIA

OR

THE HISTORY OF MARYLAND DURING PALEOZOIC TIME

BY

BAILEY WILLIS

THE HELIOTYPE PRINTING CO. BOSTON

THE CITY OF CUMBERLAND AND "THE NARROWS" OF WILL'S MOUNTAIN.

PALEOZOIC APPALACHIA OR THE HISTORY OF MARYLAND DURING PALEOZOIC TIME

BY

BAILEY WILLIS

INTRODUCTION.

Some rocks consist of materials gathered beneath the sea and are marked by the water whose currents form them. They are laid in even beds; the surfaces of the beds are often rippled; they receive impressions of seaweeds and trails of crawling creatures; and marine animals become imbedded and are preserved in them.

The materials of which such rocks are formed are chiefly sand and mud (or mechanical sediment) and lime, which occurs in the sea in solution and may be precipitated by organic or chemical means. Rivers carry these substances down in great quantities and waves breaking along the shore sweep back the pebbles, sand, and stirred-up mud. When deposited beneath the water and consolidated, the tribute from the land delivered to the sea by streams and waves becomes conglomerate (pebble-rock), or sandstone (sand-rock), or shale (mud-rock), or limestone (lime-rock); and these varieties of sedimentary rocks occur in strata, the several kinds alternating and often grading one into another.

In Maryland all the rocks west of the Blue Ridge are sedimentary rocks, as is proved by their bedding, the marks upon their surfaces, and the fossils they contain; and it is known by studies of them that a sea extended where now are the mountains and valleys of this and adjoining states. That sea was not the Atlantic Ocean. It was an interior, or mediterranean sea which spread its sediments from Alabama to Canada and from central Maryland far west across the

Mississippi Valley. At least it grew to be so extended, although it was not so wide in the earliest time of which we have knowledge. The lands which bounded it lay to the east (in part where the Atlantic now rolls), to the southeast, and to the southwest. There were also lands on the west and north, but the sea was not completely shut in. There were probably several outlets from it to the ocean.

The interior sea widened in its earlier development and later narrowed. Its shore, the line between the sea and the land, migrated far across the land as the sea was extended, and returned across the sea-bottom as the waters shrank. That migration was not unhesitating; it paused, and retreated, and advanced again and again. When the sea expanded sediments were more widely spread; when the sea retreated, old rivers stretched after it, new streams developed on the freshly bared land, and new mountain chains grew up. The geographic changes of land and sea influenced climate, modified the kind of sediment sent to the sea, changed the conditions of its distribution over the sea-bottom, and caused variations of living types. The effects may now be observed in the sedimentary rocks which formed under successively different conditions, and from these effects the nature of the changes may be inferred with more or less probability of correctness according to the distinctness of the record and the simplicity of the conditions. In order to comprehend the significance of the strata and their varied sequences, it is necessary to understand the operations and relations of three great geologic processes, which affect the extent of continents and give rise to mountains. They are the processes of erosion, sedimentation, and deformation. Fully to discuss them would require a treatise on geology, but their natures may be suggested by illustrations drawn from their present operations; operations which repeat the conditions and events of the past.

GEOLOGIC PROCESSES.

Illustrations of Erosion.

Erosion is that process by which elevations of the land are worn down toward sea-level. It is carried out by the forces of the sun

acting through the atmosphere and the sea upon the land, and by gravitation. The process may be illustrated by describing the development of a coast and the work of rivers.

DEVELOPMENT OF A COAST.

In migrating backwards or forwards a coast assumes new features according to the form of the land across which it sweeps. At the meeting of the land and sea a level line is drawn across a plain, around a hill, or along the slopes of a valley; all below that line is submerged and the line becomes the shore.

Shores are of many types. There is the coast of Maine, marked by long crooked fiords, rocky shores and islands, cliffs and steep pebbly beaches; it is like and yet unlike the California coast, which also is bold and rock-bound, but which for hundreds of miles presents an almost unbroken front to the waves of the Pacific. Few islands adorn it, and the bay of San Francisco is the only harbor that leads deep into the land. Strongly contrasting with these is the coast of Virginia, where beaches of gray sand stretch for miles in smooth curves, a barrier between the waves of the Atlantic and the lagoons which fringe the low margin of the Coastal Plain; or the marshy shore of Louisiana, including the great delta of the Mississippi, girt with muddy spits and bars which scarcely rise above the Gulf.

The character of a shore is worked out by the sea according to the aspect of the land against which the waves break. The shore is a line along which the waves attack. In the contest the sea is active, whereas the land is passive; and the edge of the land is shaped by the sea until it becomes even, perhaps, if the work goes on long enough at one level.

When a coast, migrating, takes up a new position, the shore is said to be young. Its shape is then determined by the contour of the land. When a shore has been so long established along a constant level that it is adjusted to the waves and currents of the sea, it is said to be aged. The coast of Maine remains young; that of Virginia has become aged. Youth and age are here distinguished not by the lapse of time, but by the development which may be more rapid

along low lands and upon softer rocks than across high lands and more resistant rocks.

The attack of the sea is delivered in a horizontal plane, the plane of sea-level, and in a zone a few feet above and below. The agents of attack are waves driven by the winds, sweeping rocky material and sand with them; they are checked on shallows and breaking strike blows, which often have great force. If the blow is struck against a very gentle slope under water, it glances with relatively little effect. If it is delivered against a sand or pebble beach, the sands or pebbles are redistributed till they attain a slope on which an advancing wave sweeps up only what in retreating it carries back. This is a slope of equilibrium for waves of that capacity to move the materials. If the shore be composed of coherent rock, whether soft or hard, the blows of the waves cut it away in the zone of their delivery. Any slope is chiseled away at a definite level. All the rock above that level is undermined and from time to time falls into the sea. Thus two facets are carved upon the land; the one a level bench or terrace marking the lower limit of the waves' effect, a few feet below water-level; the other a steep face or cliff from which the latest fallen rock has parted. The effectiveness of wave action depends in part upon the depth of water near shore, in part upon the strength of the waves, and in part upon the firmness and height of the land. Across low lands of slightly coherent rock, a strong sea may rapidly cut its shore until the shallows on its wave-carved terrace break the force of the attack. If then simultaneously the relative level of land and sea changes, so that the water grows constantly deeper on the terrace, the advance of the sea may progress unchecked over a wide expanse. The wave-cut terrace then becomes a broad submarine surface, which is technically described as a plane of marine transgression. It is known that such a plane was thus wrought across western Maryland, Pennsylvania, Ohio, and other central states as far as Wisconsin in an early geologic period, the Cambrian.

In thus planing down the land, waves receive and deliver to the sea the loosened rock. Their work is twofold; they roll and grind the coarser, while they sort out and sweep away the finer materials.

The onrush of the wave is succeeded by the outflow of the undertow, and as the former is constantly repeated the latter is a continuous, pulsating current. Stirred up in the dash of a breaker, sand and clay are seized and swept out by the undertow. The mill of the waves effectively grinds, efficiently sorts, and delivers its grist to the sea. The grist is assorted sand and mud, which go to make up some sedimentary rocks.

WORK OF RIVERS.

Under the influence of the weather rocks disintegrate and decay. Some constituents remain insoluble, forming soil, others pass into solution. Soil and solutions are both received by streams from rivulets, and carried down eventually to the sea. Unceasing as the dash of the waves on the shore, the work of rivers gradually moves mountains. In common parlance this is a figure of speech, but it is not so in geology. It is a simple fact, apparent when one contemplates a brook and considers how constantly it is restored by rains, while the inert rocks decay and waste away.

The effect of moving mountains, even though grain by grain, is to level down the heights to a lowest possible slope. As water will not flow on a level, so there is a minimum fall which at least is necessary to cause sediment to flow with water. If the fall becomes less, the sediment sinks. Below this very gentle slope, which at its outer margin extends beneath the sea, streams cannot reduce the land. The process by which heights of land are leveled, called erosion, progresses slowly as it nears accomplishment. The ideal lowest possible slope, which is called a base-level, is perhaps rarely reached; but plains of very low relief have resulted from time to time.

As rivers carry down the waste of land, it becomes tributary to the sea. Each stream delivers a proportion according to the extent and character of its drainage area. From heavily-loaded rivers deltas are built out against weak waves, but relatively strong waves and currents seize the tribute and sweep it off. A delta also ultimately ceases to develop and, unless submerged by subsidence, becomes the spoil of the waves.

The work of rivers being recognized from the facts of the present, it is recognized that the same work was done by rivers which long since disappeared from the face of the earth, and their existence is sometimes vaguely recorded in sedimentary rocks.

Illustrations of Sedimentation.

Sedimentation is that process by which the waste of the land is distributed and deposited beneath the sea. The work of distribution is performed by currents of the sea which are caused chiefly by the winds, and the settling of the waste is due to gravitation. The winds are driven by the sun's heat and directed by the revolution of the earth, and thus like erosion this process of sedimentation is the work of the sun and gravitation.

SANDS ON THE ATLANTIC SHELF.

Waves roll in from an uninterrupted course of several thousand miles upon the coast from Long Island to the Carolinas. Over the stormy North Atlantic easterly winds are frequent and powerful, and the waves they drive so far strike the coast with great force. Across broad stretches the shore is low with intervening bluffs of moderate height. From the bluffs the waves remove gravel, sand and clay, which they sweep along shore, building barrier-beaches before the lowlands and across shallow bays.

The rocks opposed to the powerful waves are incoherent. They are deposits of various sorts, but all have been subjected to influences of weather and of water so long or so often in the past that they have become mixtures of clay and sand which but slowly undergo further decay in the process of erosion. Easily removed, they may be sorted and distributed, and the assorted deposits consist of the most durable minerals.

Sorting and distributing begin the moment the materials fall into the line of breakers. The currents along shore transport them, dropping out the coarser sands when the weight of the particles exceeds the carrying power of the current; and the waves seize upon these sands and build beaches. The shore currents sweep on with the finer

sand and clay until the sediment sinks into the undertow, which flows seaward down the slope of the ocean's bottom. That slope is very gentle for 50 to 100 miles from shore and then grows steeper. Upon the broad shelf the water deepens gradually to 100 fathoms; beyond it becomes generally more than 3000 fathoms deep. The undertow and off-shore currents efficiently carry the fine clay out to the margin of the shelf, but there the movement is checked by the great body of deep water and the load of clayey sediment is deposited. Between the outer zone of clay deposits and the inner limit of beaches, the shelf is spread with sands, coarser near the shore, finer toward the ocean. These sands have been beaten on the beaches, worn, tossed, and washed. They are concentrated till they consist of little else than quartz and fragments of hard shells. Near shore they are deposited by currents which eddy and pulsate under the influence of tides and storms, producing irregularities in the coarser beds; further offshore they settle out from gentler and steadier currents, which lay them in even beds. There are strata of white sandstone among the rocks of Maryland, which are composed of beach-worn sands deposited off a shore resembling the present Atlantic coast.

LIMY MUDS IN THE GULF OF MEXICO.

The bottom of the Gulf of Mexico is covered with fine-grained, limy mud. The waters of the Gulf move as part of the great South Atlantic ocean current, which enters through the Strait of Yucatan and passes out through the Strait of Florida. The current flows from equatorial regions and is warm; it sweeps by the mouths of the Amazon and Orinoco and is charged with immense quantities of sediment and of substances in solution which those rivers bring to the sea. Much is deposited in the Caribbean deeps, but the stream enters the Gulf still charged with fine silt and there receives the contribution from the Mississippi. Circulating in eddies the waters lose their sediment, which is distributed somewhat evenly over the bottom, constituting a fine ooze. The warmth of the water is favorable to the development of manifold forms of floating marine life, which take carbonate of lime from the water and dying contribute it to the

volume of sediments. Thus the ooze becomes limy or calcareous through organic agencies. It may become limestone if the proportion of lime be sufficient, or calcareous shale where the inorganic sediment predominates, or limestone and shale in alternation where the warm life-bearing waters of the ocean current meet the occasional muddy floods of the Mississippi. Conditions similar to these prevailed widely throughout the interior sea of America during several distinct epochs of Appalachian history, and they are recorded in limestones and shales of the sedimentary rock series.

Illustrations of Deformation.

Deformation is the name given to that process which results in changes of form of the earth or of some part of the earth. Although changes of form which have gone on in the past or which are going on now have been observed in all lands, the movements which result in change of form and the causes that effect them are not yet clearly understood.

Movements whose effect is apparent in rocks are movements of the crust of the earth, the word crust being used to signify that portion of the earth which lies within a depth of a very few miles below the surface on which men live. Not long since it was generally believed that there was a crust which, having solidified, was distinguished by its solid condition from a molten interior. Many competent thinkers now incline to the hypothesis that the interior also is solid, and not distinguished from the exterior except by physical and chemical differences due primarily to pressure and secondarily to heat. But observation can apply only to an external shell some 5 to 10 miles deep, and this may conveniently be called the crust without defining its relation to the interior.

Movements of the crust may probably occur in any direction, but they are manifested in effects which may be attributed either to vertical movements, that is those in the direction of a plumb-line, or to horizontal movements, that is those in the plane of a water-level surface. Some of the effects of these two classes of movement and the manner in which they are interpreted may be stated.

EXAMPLES OF VERTICAL MOVEMENT.

In the vicinity of Washington and Baltimore excavations here and there expose granite, or an allied rock, beneath a stratum of coarse gravel which was spread by waves breaking along a former shore. At present the bed of gravel lies high above the sea. In relation to the sea it has been raised to its present elevation by a vertical movement of the crust.

The granite beneath the gravel is of a coarse crystalline texture produced in rocks once molten and cooled very slowly beneath the surface. The allied rocks, schists, are divided by many partings into thin leaves, usually standing on edge. This peculiar lamination associated with certain crystalline characteristics is an effect of mechanical and physical alteration under conditions of enormous pressure. It is developed only at great depths. If these characteristics of the granite and schist are correctly interpreted the rocks beneath the gravel bed have risen many thousand feet relatively to sea-level to reach their present position. This rise is equivalent to the growth of a very high mountain range, but it may never have resulted in a great elevation above sea as the atmosphere constantly weathered off the rising surface of the land. The height of any mountain range is the difference between the total uplift above sea-level and the amount eroded. During long epochs the uplift about Baltimore was very slow, and may not have resulted in great heights; yet during other episodes accelerated development may have produced conspicuous ranges. The most significant fact is the vertical movement in the earth's crust.

Mountain ranges are the expression of relatively rapid uplift, which may result either from direct vertical movement or indirectly as an effect of horizontal movement. The Appalachian mountains have long been interpreted as caused by wrinkling of the earth's crust, an effect of horizontal movement, and such an Appalachian range probably existed formerly. But these mountains of to-day are a result of direct vertical movement, as may be explained briefly here, although the detailed account belongs to a description of the later events of geologic history in the province.

Being constantly exposed to the destructive attack of the atmosphere, mountains diminish in mass as soon as they cease to grow vigorously, and ultimately they are worn away. Prolonged as the process of destruction may seem to man, it is a brief geologic event. All existing mountains have developed during the later geologic periods; some are still growing; others are passing into their decadence, becoming hill regions, and will become plains. Mountains rise from plains and give place to plains.

During a recent geologic period, the Cretaceous, the site of the Appalachian mountains was an extensive plain from Canada to Georgia, from Maryland to Ohio. Lines of that surface are seen in the long level crests of North Mountain, Sideling Hill, and the Alleghany Front. The former plain has been elevated unequally, most along the axis of the highest ranges, little or not at all about the Atlantic and Mississippi margins, forming a very broad dome about 4000 feet high. In that dome rivers and rivulets have engraved the valleys of the Appalachians along softer beds of rock, while the harder still maintain their heights as ridges.

The uplift developed and has been sculptured to its present aspects since the Cretaceous period. Before that period, as will be shown later, the wrinkling of the earth's crust, to which the growth of the mountains has been attributed, was completed, and whatever ranges resulted from the wrinkling had been worn away. The present Appalachians, therefore, are not an expression of that horizontal movement (wrinkling), but of a vertical uplift, which is of later date.

Subsidence of the earth's crust is a vertical movement which is the reverse of mountain growth. The evidences are many that areas of wide extent as well as more limited ones have subsided with reference to sea-level from time to time throughout all the known geologic past. Lands have sunk beneath the sea, causing the shore to migrate far, and upon the newly established sea-bottom sediments have accumulated many thousand feet thick. Upon successive strata frequently occur the marks of shallow water, proving that the deepening basin was as rapidly filled. The thickness of strata gives a measure of the amount of subsidence, and in mountains the occurrence of strata

Drawn by S. B. Nichols from a Sketch by the Author.

North Mountain in the Distance.

Potomac Valley in the Distance.

Round Top.

Tonoloway Ridge.

VIEW FROM SIDELING HILL, LOOKING EAST.

formed in a subsiding basin is a demonstration that the downward movement in such a case was succeeded by one in an upward direction.

EXAMPLES OF HORIZONTAL MOVEMENT.

Movement of a segment of the earth's crust in a horizontal direction appears to be indicated by the folds which occur in strata that were once flat. The familiar illustration of a fan may make this clearer. When the fan is opened wide it is flat, and the outer sticks are far apart; when it is partly closed the paper is thrown into folds, and the outer sticks have approached. Folds which in some respects resemble those of a fan occur in beds of limestone, of coal, and of other rocks, which were originally spread flat. It would seem that the outer edges of the folded zone had approached, as do the outer sticks of a fan. In the Appalachian mountains there is such a folded zone, which before it was folded, was approximately 100 miles or more in width and, being folded, is now 65 miles wide. That is to say, the outer limits of the zone have come nearer together by 35 miles. Whether, as has been commonly held, this approach be due to shrinkage of the earth or not is not here discussed. The fact of horizontal movement within the zone of folding is established.

The movements that resulted in Appalachian folding occurred during the ages whose events are to be described, and the conditions leading up to and attending the development of the folds will be set forth so far as they are understood. The mechanical laws which govern the location and size of folds in strata are in fact simple, although the effects are so stupendous in magnitude that the mind may at first find them incomprehensible. A series of strata twenty thousand feet thick may fold like a pile of paper, if the forces are adequate.

Relations of the Three Processes.

Deformation, erosion, and sedimentation are related in so far at least as the first provides conditions essential to the activity of the other two, and the second supplies the materials for the last. That is: Deformation initiates an activity which results in erosion and sedimentation successively. Many theories have been advanced to show

that erosion and sedimentation result in deformation, and that the cycle of processes is complete, but the conclusion has not been demonstrated. Deformation may be an effect of an independent cause, or causes, which would be the more remote cause of all three processes. As the events of Appalachian history followed from the activity of the three processes, the relations of the processes may advantageously be more fully explained.

The oceans are contained in broad basins within which are profound deeps, and the continents are wide elevations above which mountains rise. The larger inequalities of the surface of the earth are so distributed that two-fifths of the total area lie between 11,000 and 16,000 feet beneath the ocean, with a mean depression of 14,000 feet below sea-level; and one-fourth of the entire surface falls 1000 feet below and 5000 feet above sea-level, with a mean elevation of 1000 feet. The former, that great expanse lying approximately 14,000 feet below sea-level, has been called the oceanic plateau; the latter is known as the continental plateau. The facts are graphically set forth in the following diagram, which was first prepared by Gilbert,[1] after data assembled by Murray.

The inequalities are the net result of deformation during geologic ages. As the margin of the continental plateau is submerged, the oceanic basins are now more than filled by the sea. If in consequence of deformation the basins should deepen, the waters would recede from the continents; or apparently the same result would follow if the continental plateau should rise. But there would be a distinction between the two effects, in that a deepening of the sea basins would affect the shores of all continents alike, whereas the uplift of one continent would probably not be shared equally if at all by others. There is evidence to suggest that the oceanic basins have deepened materially during certain episodes of the earth's history, and there are facts to prove that continental masses have been raised. Mountain uplifts have occurred even more frequently and more energetically.

The effects of deformation which result in the elevation of moun-

[1] Continental Problems, Bulletin G. S. A., Vol. IV, pp. 179-190, 1893.

GENERAL VIEW OF ARCH OF ORISKANY SANDSTONE ON NORTH BRANCH OF THE POTOMAC NEAR JUNCTION WITH SOUTH BRANCH.

DETAILED VIEW OF ARCH OF ORISKANY SANDSTONE ON NORTH BRANCH OF THE POTOMAC NEAR JUNCTION WITH THE SOUTH BRANCH.

tain masses or continental masses above the sea thereby favor the process of erosion, whose tendency is to grade down the land. If an uplift be accomplished, it will be graded down by erosive processes in time, no matter how great its magnitude. And when the degradation is completed to a plain at the lowest possible slope, then the activity of mechanical erosion pauses.

A principal result of erosion is the preparation and delivery to the sea of land-waste, with which sedimentary deposits are built up. The

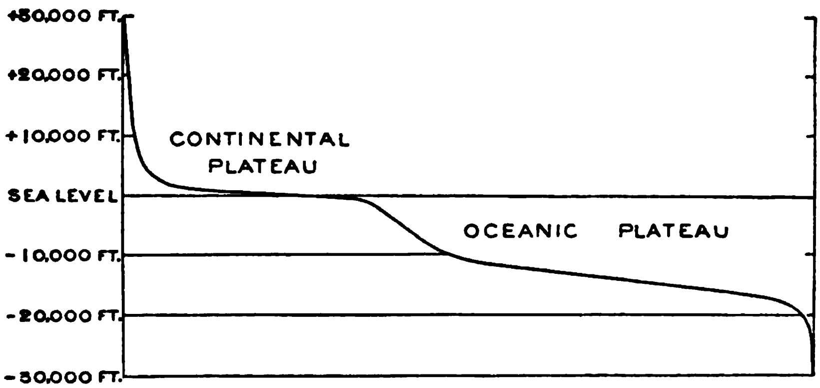


FIG. 1.—Generalized profile, showing relative areas of the earth's surface at different heights and depths. The width of the diagram from side to side stands for the entire earth's surface. The curve shows the relative extents of the continental and oceanic plateaus and adjacent slopes. These relations are expressed independently of the distribution of land and sea.

rate of accumulation of sediments depends upon the rate of erosion, though indirectly in many instances; but in general it is true that when lands are prevailingly low, sediments accumulate slowly, and sedimentation may fail when erosion becomes inactive.

The three processes may be thus characterized: Deformation initiates activity; erosion destroys uplifts; sedimentation reconstructs rocks and records events of geologic history.

PALEOZOIC HISTORY OF MARYLAND AND ADJACENT STATES.

The Point of View.

Geologic history is an account of development; it may be of the development of continents and oceans, of lands and seas, of mountains and river systems, that is of the physical history of the earth; or it may be of the evolution of plants and animals, that is a history of the organic life of the earth. Organisms obey a general law of change. The nature of the variation in any case is an effect of inherited tendencies and of an effort toward adaptation to physical environment. Environment is modified in epochs which are brief as the earth's history is measured, and the changes react on faunas and floras. Thus in order to understand the life history of the globe it is necessary first to know the physical history.

This article is a contribution to the study of the physical changes only. It is an attempt to interpret the mechanical characters of certain sedimentary rocks, in the order of sequence as they occur, and in accordance with the effects of deformation, erosion, and sedimentation now observable on continents and about their shores. Some of the episodes which are comprised in the review are the growth and wasting of several mountain systems, the expansion of plains of continental extent and their submergence beneath widening seas, the construction and migration of extensive coastal plains, the upfolding and dislocation of sedimentary strata from 2 to 6 miles thick in a zone a hundred miles wide and fifteen hundred miles long, and the withdrawal of the sea from the province over which it had circulated during many million years. The magnitude of the phenomena is co-ordinate with the lapse of time, and both surpass man's grasp, but the evidence of the facts is unmistakable in all the broader relations.

The Place and Time.

The scene of this history is eastern North America, comprising a region between the present Mississippi Valley on the west and an

Zon
strata
merged

Ar
Camb

Lan

Prob
brian ti

Lin
uncon
the tre

unknown limit on the east where now the Atlantic rolls. The region comprised a sea and a land. The sea lay west of the land; the land stretched eastward beyond the present extent of the continent. The shore along which the western sea met the land migrated during ages far eastward and again far westward with many minor oscillations back and forth, and the areas of land and sea shrank and expanded each in opposition to the other. The land may be called the continent of *Appalachia*. The sea was the mediterranean of North America.

The time of this history covers the Paleozoic era, the era of ancient life, which is distinctly recognized as a grand division of geologic time represented by rocks known in many parts of the world. The Paleozoic era was many million years, how many cannot safely be estimated. Since its close other millions of years, probably fewer, have elapsed. Before its earliest episodes, longer time than has since passed had been occupied by events which are recorded in older rocks. Thus, the era of ancient life, the Paleozoic, is an early part of the later half or of the latest third of geologic history.

Rocks of the Paleozoic era are recognized by the fossils they contain, most of which represent creatures that lived on the sea-bottom. Except the vertebrates, which, however, appeared as fishes early in the era, the several types of organic structures existed in varied development at the beginning of the Paleozoic, and their evolution has since involved thousands of species and hundreds of genera, of which but a very few survive unmodified. The development successively of different forms and the corresponding disappearance of groups of preceding types occurred, perhaps gradually on the whole, but in limited districts where conditions varied rapidly with sharper distinctions between the older and newer forms. These distinctions correspond to changes in the nature of the rocks, which were themselves related to changes in the physical conditions of the sea; and the variations in the organisms are due to an extinction of the forms which were too conservative in their habits and to the immigration or development of others that could adapt themselves. The failure of any type to perpetuate itself may be due to misdirected development under stimulus of too favorable an environment, or in cases of unfavorable environment to inadaptability or weakness.

According to the facts of the three most marked episodes of variation of species the Paleozoic era is divided into four periods, the Cambrian, Silurian, Devonian, and Carboniferous, named in order from earliest to latest, and the close of the Paleozoic era is defined by the general disappearance of the ancient forms of life, and by the appearance in succeeding strata of types more nearly allied to those of the present. For more detailed information on the facts which determine the classification of geologic events, the reader is referred to textbooks on geology.

Appalachia before the Paleozoic Era.

THE PRE-CAMBRIAN ERA.

The rocks of pre-Cambrian Appalachia fall into four classes, which differ in their genesis and accordingly signify distinct episodes of history. These are the schists, the granites and allied igneous rocks, volcanic rocks, and sediments. The schists are the oldest and their origin is in many cases obscure. They may have been in part sedimentary, but are known to have been to a large extent of igneous origin. Their significant characteristic, however, is the arrangement of their minerals in such manner that the longer axes of the crystals are parallel. The minerals which have assumed a parallel relation are not the original minerals of the rock as it first formed, but are those which have developed during chemical changes under conditions of extreme pressure. This structure gives to the schists their tendency to cleave in thin layers along parallel planes, and is one which is acquired only at great depth in the earth's crust. Therefore whatever may have been the origin of the rock from which the schists are derived, it is certain either that it formed at great depth or after having been consolidated near the surface was deeply buried. The granites and the allied rocks exhibit a coarsely crystalline texture uniform throughout large masses, which is peculiar to rocks which have been molten and cooled slowly. The conditions for such cooling exists only at some distance beneath the surface, and thus the granites also indicate that the rock mass of which they form a part was deeply

buried when they cooled. It will presently be shown that the schists and granites were nevertheless exposed to the atmosphere at the surface of the land in early Paleozoic time and that they had, therefore, risen from the depth at which they developed their characteristic structures. Similar phenomena of granitic intrusions took place late in the Paleozoic era in New England, and at still later dates in the Rocky Mountains and Sierra Nevada. The uplifts by which the deeply buried rocks were raised to be bared by erosion constituted mountains in pre-Cambrian time, probably as they did late in the Paleozoic and do now. Thus the process of mountain growth is seen to be one of great antiquity.

The pre-Cambrian volcanic rocks still retain structures, such as lines of flowing, peculiar to lavas which have been poured out in a molten condition and cooled at the surface of the earth, and they tell of volcanoes whose activity was intense and which were widely distributed. In their chemical composition as well as in their internal structures these rocks are closely related to lavas erupted in later times, and the resemblances serve to strengthen the inference that the western portion of Appalachia in pre-Cambrian time was the scene of events since reproduced in the western regions of North America.

The existence of high lands was favorable to erosion, and an accumulation of sedimentary strata in adjacent seas was a necessary consequence. Those strata were subsequently deeply buried under Paleozoic formations, and if now exposed to view appear distorted as parts of mountain masses. Their relations to later sediments are obscured and, as the pre-Cambrian rocks very rarely contain fossils and none have been found in their supposed representatives in the Appalachian province, it has not been possible to identify them positively. The strata now considered to be the oldest of the Appalachian series may be pre-Cambrian or Paleozoic. However, in the Smoky Mountains of North Carolina is a group of more or less altered shales, sandstones, and conglomerates which is probably of pre-Cambrian age. It was named the Ocoee group by Safford, who correctly perceived its probable great antiquity, and it has been traced into

Georgia by Hayes and into Virginia by Keith. Where the strata of the Ocoee group occur in contact with the still older schists and granites it may be seen that the sediments are composed of the slightly sorted and rearranged detritus of the more ancient rocks, as sometimes happens along a shore. The story of that coast may not be written until the distribution and relations of the Ocoee are more thoroughly known, but it is probable that the facts bear witness to the positions of the western shore of Appalachia in its migrations, during the later epochs of pre-Cambrian time.

At the beginning of Paleozoic time Appalachia had thus already acquired a complex rock structure, and the surface of the land corresponded to the truncated bases of earlier mountain ranges. There is reason to believe that it was hilly, but not elevated, and that the rocks were deeply decomposed as their representatives now are throughout the Piedmont region of the Atlantic border. The interior sea washing the coast of Appalachia on the west was then a strait, probably not more than 100 miles in width and 1,500 miles long, extending from the Gulf of St. Lawrence along the line of the Champlain trough to the great Appalachian Valley of New York, Pennsylvania, Maryland, Virginia, and Tennessee, into Alabama. Its southern or southwestern connection cannot be traced, and its western shore is not accurately determinable, but its eastern side lay not far from the present line of the Blue Ridge through Maryland and Virginia. The absence of pre-Cambrian and early Cambrian sediments across the central states shows that there a land area extended, and it was bounded on the west by a second narrow sea whose sediments now form part of the mountains of British Columbia, western Montana, Idaho, and Utah. Thus the continent of North America was in that early day divided by two straits into three continental areas; the eastern continent, Appalachia; a central land extending to the Rocky Mountain strait; and a western whose farther Pacific limit is not yet made out.

SUBMERGENCE DURING THE CAMBRIAN PERIOD.

THE BASAL UNCONFORMITY.[1]

The pre-Cambrian schists and other rocks not of sedimentary origin are in contact with and underlie sedimentary strata from North Carolina to Canada. At the surface of contact the schists, the granites intruded into them, and dikes of formerly molten rock which cut the granite, all end abruptly. The surface was planed across their complex mass after they had acquired fixed relations, and it was probably closely parallel to a general slope developed by erosion on the Appalachian land. The strata which rest upon the old rocks are of varied character at the contact. In some places they consist of the partly decomposed minerals of granite or the less easily recognized particles of weathered schist; and elsewhere the sediments were clayey or of quartzose sand. The granitic sands are often deposited on or near a granite mass from which they were derived, and of the other sediments those whose original character can be recognized lie frequently in similarly close juxtaposition to their parent rock. The clayey beds and quartz sands were partially washed and sorted from the more thoroughly decomposed schists and granites. Thus the source of these sediments was the weathered surface of various rocks, the land surface of Appalachia, and the waters which received and rearranged them played close to the source. These conditions are associated only along shore, and where this contact of the sediments upon the older rocks is found, there was once a shore with bluffs and beaches and bars.

The surface of contact is an unconformity which marks a great interruption in the geologic record—the schists and granites are very much older than the sediments, as has been indicated in describing

[1] An unconformity marks an hiatus in the geologic record. It is that relation between a sedimentary stratum and any older group of rocks which exists when the older rocks have been involved in uplift and subsidence prior to the deposition of the younger stratum. The movement may have been effected without disturbance, or the rocks may have been completely sheared and folded. The rise may have resulted in very slight effects of erosion or in the dissolution of mountains. The time corresponding to the hiatus may have been a brief episode or a great era.

the pre-Cambrian history—but the close of the hiatus is not everywhere of the same date. This is determined by the age of the strata deposited on the eroded surface of the older rocks. Throughout much of the Appalachian Mountains, the oldest strata next to the pre-Cambrian rocks contain fossils which belong to very early, generally low, types of life, and by which the strata are identified as of early Cambrian age. Elsewhere, strata of the Ocoee group lie upon the pre-Cambrian. They contain no fossils but, as has already been explained, they are probably older than the Cambrian.

An explanation of the different dates marked by the close of the hiatus is not far to seek. Where the Ocoee strata rest on the old schists and granites, there was the shore of the sea during an episode of that date; where the early Cambrian sands were deposited in a similar relation was the shore of a wider sea, which at that later date spread further upon the Appalachian land. In technical phrase the Cambrian strata overlap the Ocoee strata in the greater part of the province. Hence we may draw the conclusion that Appalachia had for some time been subsiding with reference to sea-level when the forms of life which mark the early Cambrian appeared in the waters of the adjacent strait.

CAMBRIAN STRATA.

The sequence of strata deposited during the Cambrian period may briefly be described as composed of coarser sediments at the base of the series followed by finer sediments above; or as consisting of mechanical deposits in the lower part mingled with but little material of organic or chemical origin, and in the upper part chiefly of organic or chemical sediments with only the finest mechanical products of rock disintegration. The lower strata are conglomerate, sandstone, and sandy shale, the upper are calcareous shale and limestone. Generalizing local details which mark fluctuating conditions in limited districts, the above statement is true of the entire Appalachian province from Alabama to Canada, and from that comprehensive fact the nature of the geographic changes is broadly to be inferred.

When the early forms of marine life, which indicate the beginning

of the Cambrian period, appeared along the shore of Appalachia, that continent was subsiding, as has been stated. The coast of a sinking land is characterized by features which cause peculiarly local and varied sediments along a narrow littoral zone. Valleys, being flooded by the relatively rising sea, become bays or estuaries like the Chesapeake. If they are extensive they receive and retain all the sediment brought down by tributary rivers, as is now the case with the great volumes contributed by the Susquehanna, the Potomac, and other streams flowing into Chesapeake Bay. It is floored with "blue mud" almost to Norfolk, but beyond the Capes the ocean bed is of sand.

Between the estuaries extend higher lands, as peninsulas, and against their headlands waves beat, carving sea cliffs, from which pebbles and sand are distributed over the adjacent sea-bottom. The powerful waves of the Atlantic abrade, sort, and carry this material very efficiently, and our coast is bordered with clean, sandy beaches; but the waves which broke on the shore of Appalachia were weak. In many localities they failed to sort the decomposed rock, which they washed gently to a resting place near its source. Elsewhere beating more strongly, or aided by local currents, or having the partly sorted detritus of an older sedimentary rock to handle, the waves spread clayey sands or sands consisting chiefly of clean quartz. Thus along the subsiding shore at any time, deposits of river mud accumulated in estuaries, and wave-wrought, coarser materials of various kinds were spread along the coast-line. In addition to the variations along the coast, there was a more uniform change in the character of the deposits from the coast seaward. Coarser sands gathered near shore, and finer sands and clay subsided farther out.

Although the general movement of Appalachia was a sinking one, there were episodes when the continent stood at a constant level or even rose with reference to the sea. In the former case the rivers silted up the estuaries and the waves accomplished more thoroughly the abrasion and sorting of detritus along shore. In the latter case, as the estuaries again became valleys, the rivers resumed their courses and, scouring out the accumulated mud, swept it to the sea,

while the waves, withdrawn from their previous advance, washed over the sediments they had most lately distributed. Such oscillations of level may account for the alternation of coarse and fine detritus in the mechanical sediments and for variation in the degree of concentration of sands, which sometimes consist of minerals easily decomposed mingled with quartz, and again of concentrated quartz, one of the most durable minerals.

The thickness of the mechanical Cambrian sediments varies in different parts of the province. In Georgia and Tennessee, where they probably succeed the Ocoee group, their volume is great. They are there represented by the strata of Chilhowee Mountain, 2,500 feet thick, and by the Rome sandstone, 3,000 to 4,000 feet thick. In Maryland the Loudoun, Weverton, Harpers and Antietam formations aggregate 3,000 feet. In Massachusetts the Vermont quartzite is 900 feet, and the Becket gneiss possibly 2,000 feet thick.

The area over which these formations originally extended, but from which they have in large part been eroded, can never be known; nor could the land area from which they were derived be estimated, even if their original volume were calculated. But it is probable that the area eroded very considerably exceeded the area of deposit and that the tributary district of Appalachia was worn down but a few hundred feet at most to provide sediments locally 2,000 to 4,000 feet thick.

The Cambrian sandstones and shales were succeeded throughout the province by calcareous shale and that by limestone. Fine clay, the principal component of the shale, represents the waste of a deeply eroded land, or one remote from the place of deposition. Lime, the chief constituent of the limestone and an important one of the shale, was precipitated from the sea-water by organic or chemical means. The source of material of calcareous shale and limestone thus differs from that of sandstone and sandy shale, and the occurrence of the former in sequence on the latter implies corresponding changes of conditions. The effective changes were two. The one was the erosion of surviving land areas to a condition of very low relief, and the other was the extensive widening of the waters from the Appalachian strait to a mediterranean sea.

That Appalachia had become a lowland is an inference justified by the facts of prolonged subsidence and erosion indicated by the mechanical sediments, but it may be pointed out that the sequence of fine calcareous shale and limestone is evidence which confirms the inference. Where lands are high and declivities are steep, rocks are bared of soil and are broken by variations of temperature and by frost. Disintegration proceeds rapidly and chemical decay is insignificant. Where lands are low and slopes gentle, the reverse is true. There rocks decompose, forming deep beds of clayey soil. Thus different topographic aspects yield diverse sediments, and in the sequence of Cambrian strata is the record of the passing of the hills of Appalachia and on their sites the expansion of broad plains. Even the low relief of plains wastes away, though slowly, and as the surface sinks to so gentle a slope that rivers remove but little sediment, the mechanical contribution from the land to the sea fails. This is a condition to which reference will repeatedly be made to explain the character of some Paleozoic strata.

The widening of the strait eastward over Appalachia has been described. It can never be known where that migration of the coast halted, as the sediments which recorded it have been eroded, but it is by no means improbable that the sea swept over the eastern districts to or beyond the present Atlantic shore and that land areas lay still further east. The expanse of the sea westward is more definitely traceable. Strata occur along the western side of the great Appalachian Valley in Tennessee which are of early Cambrian age, and are of such relative thickness and coarseness as to indicate that they accumulated not far from the western shore of the strait of that date. Thence westward the rocks now visible at the surface are much younger. They cover the Cambrian deposits and the pre-Cambrian rocks across the Mississippi Valley to Missouri and Wisconsin; and there where the pre-Cambrian rocks reappear at the surface, the strata which rest upon them at the basal unconformity are of late Cambrian age. The absence of earlier Cambrian strata and the presence of later deposits of that period, as determined by the fossils, demonstrates the migration of the shore westward from the

Appalachian strait to Missouri and Wisconsin, a distance of 300 to 700 miles. The effect was similar to that which would now ensue if North America should slowly subside until the Gulf of Mexico and Hudson Bay were joined in one great mediterranean sea.

In this sea, whose strata still cover at least 160,000 square miles and which was probably much more extensive, the principal sediment deposited was carbonate of lime. The resulting limestone was approximately 1,000 feet in Missouri, 3,000 to 4,000 feet in eastern Tennessee, and 6,000 feet in Pennsylvania. If the average thickness be assumed to be only one-fourth of a mile, the volume of limestone covering 160,000 square miles is still 40,000 cubic miles—a mighty stratum truly. If, further, it be assumed that the percentage of carbonate of lime is but one-half, the volume of that constituent is 20,-000 cubic miles, the other half being fine clay. These estimates are well within the limits of fact. Whence came, then, this vast volume of calcareous sediment and how was it deposited, organically or chemically?

The pre-Cambrian crystalline rocks of Appalachia and other land areas about the mediterranean sea, eroded contemporaneously or just before the limestone formed, first suggest themselves as the source of the lime, but it can be shown that the source is inadequate for the supply. Approximately stated, those rocks consist by weight of about 80 per cent of silica, alumina and iron oxides, which all go to make up the insoluble mechanical constituents, and of but 5 per cent of lime. To the latter we may add the same proportion of magnesia, which passes into solution and may be precipitated with it. If in this rough estimate we pass lightly from measures by weight to measures by volume, we should have 8 feet in thickness of sand and clay deposited for each 1 foot of lime over the same area. Or, considering that sand and mud are deposited chiefly along shore, whereas the lime is spread widely over the sea-bottom, the former should be several times thicker in proportion. In Cambrian strata no such volume of sandstone and shale is known or is likely to have existed; therefore, the contemporaneous contribution of the lime from Appalachia and other lands to the mediterranean is inconsistent with

facts. But the difficulty vanishes if the idea of a contemporaneous source on land be abandoned for the assumption that the lime had been derived from lands eroded during pre-Cambrian ages and had been stored in the waters of the ocean. It must then, however, be shown in what manner the character of the mediterranean specially favored the precipitation of lime and so caused the unusual deposit of limestone. This can best be done by reference to appropriate organic and chemical conditions.

Life flourished in the Cambrian sea. Walcott has described many species covering a wide range of forms which inhabited warm shallow waters. The limestone is fossiliferous throughout its occurrence to the extent that some remains of organisms may be found in any large mass of it, and locally they may be crowded closely in certain strata. Thus the fossils bear evidence that the waters were favorably warm and shallow and afforded food, and that living organisms produced part of the limestone. There is no doubt that any part of the lime which forms these fossils was organically deposited, but there is a large part of the limestone to which that conclusion does not necessarily apply. The fossils are generally imbedded in a crystalline or pulverulent matrix, which shows no organic structure even under the microscope. An assumption that this calcareous material was of organic origin is therefore not supported by direct evidence; the structure of the rock, on the contrary, resembles that of crystalline limestone now forming as a chemical deposit in the Everglades of Florida, or of pulverulent calcareous ooze chemically precipitated in the same waters.[1] Hence the conditions possibly favorable to chemical precipitation of carbonate of lime should be considered.

Chemical researches into the permanence of bicarbonate of lime in solution and the solubility of monocarbonate of lime thrown out of solution differ widely in results and do not at present afford satisfactory data. According to some investigators, the monocarbonate is very easily soluble; others, apparently equally careful, find it to be but slightly so. At the present time ocean water appears not to contain more than a part of the lime it might dissolve and hold in

[1] Conditions of Sedimentary Deposition. Chicago, Journ. of Geol., Vol. I, p. 512.

solution as bicarbonate, and monocarbonate of lime is apparently not chemically precipitated from it. Nevertheless, delicate and minute shells of pelagic organisms sink through as many as 12,000 feet of ocean water from the surface to the bottom, where they accumulate undissolved, and this in spite of the fact that they contain the strong solvent, carbonic acid, which is produced by decay of the organism. This fact indicates that the solvent power of ocean water for the carbonate is not great. Of the conditions which may result in the chemical precipitation of the carbonate, concentration of the solution is that which is most effective, but mechanical agitation and aëration appear to be only less so. Thus tufa, a deposit of carbonate of lime, forms where there break waves of waters which do not otherwise precipitate it. And agitation may suffice to separate out the carbonate from salt water only slightly more concentrated than oceanic brine. The European Mediterranean, being concentrated by evaporation in spite of the great rivers flowing into it, is more alkaline than the Atlantic, and the difference, though slight, appears locally to favor the formation of limestone, a crystalline deposit of which has been dredged at the mouth of the Rhone.

Frankly admitting that the composition of ocean water in Cambrian time is unknown, and recognizing the futility of comparisons with the percentage of lime in solution in the ocean to-day, we may compare the waters of the Cambrian mediterranean with those of the oceanic basins of the same time. The Cambrian mediterranean sea was broad and shallow, of such extent as to develop currents within its own area, and probably so related to the greater seas as to receive and discharge oceanic currents. Thus the waters were in circulation and influenced by the enclosing lands to eddy round and round. Of this fact the widespread distribution of the fine clay which forms part of the limestone is evidence. Evaporation of waters so circulating probably led to concentration of the salts held in solution as is now the case in the Mediterranean, and considering the great mass of Cambrian limestone which exhibits crystalline or granular rather than organic structure, it is not improbable that the effects were sufficient to cause chemical precipitation of carbonate of lime.

This great Cambrian limestone is an extraordinarily uniform, massive, and extensive bed of rock. In course of succeeding ages it was deeply buried beneath later sediments, and when strains developed in that part of the crust of which it was part it profoundly influenced the folding which ensued. Paleozoic strata of the Appalachian province are folded with remarkable parallelism and simplicity. This and other features, which have made that structure a type with which other regions the world over are compared, result from the character of the great limestone.

No cataclysm, nor even any marked change in physical conditions, closed the Cambrian period. The sea widened its boundaries to an extreme limit. Its warm and shallow waters gave the life of the time a rich opportunity for development, and there ensued material variation of species and genera. A new fauna was developed which has been called lower Silurian or Ordovician, and the period of which it characterizes the first part is known as the Silurian period.

THE SUBMERGENCE CONTINUED INTO THE SILURIAN.

The separation of certain strata, called Silurian, from those which preceded, and which are called Cambrian, depends upon the occurrence of fossils recognized as Silurian species. In the Appalachian province the plane of separation lies in the great limestone, in a position which has not yet been accurately worked out, but it is known that the lower part, perhaps two-thirds of the thickness, contains Cambrian species, and the upper part carries Silurian species. Thus the conditions favorable for the accumulation of limestone, the expanse of shallow sea and lowlands, continued for a long time after the beginning of the Silurian period.

This fact of the long-continued prevalence of the sea over interior North America in Cambrian and Silurian time is worthy of a pause in the recital of events, as it bears upon two questions of great interest—the permanence of continents and the activity of the forces of deformation. It has been pointed out that the greater inequalities of level in the earth's surface define a continental plateau and an oceanic plateau, the former lying 15,000 feet higher than the latter.

The subsidence which permitted the Appalachian strait to expand to the width of the mediterranean sea amounted to but a small part of this difference, as the land was low before submergence and the sea never became very deep. A sinking of 1,000 feet might suffice to account for the geographic changes. The degree of subsidence can hardly be considered to interrupt the permanence of the continental plateau.

The antiquity of the earth readily suggests the idea that she is growing old, that is, inactive; the forces which produced continents and mountains in the long past ages are dying out, it is said. But North America is to-day more mountainous than it was in early Silurian time. Where, in consequence of a long cessation of deformation, broad plains then extended just above and just below sea-level there are now mountains of recent growth. In tracing the Paleozoic history of Appalachia we shall find little proof that the earth has grown old, but much evidence that there have been epochs of activity in alternation with epochs of inactivity of the deforming forces.

Emergence During the Lower Silurian Period.

THE RETREAT OF THE SEA.

Throughout the Appalachian province the great limestone is succeeded by a deposit of shale. The constituents of the shale are clay and fine quartz sand. In many sections it is fine and calcareous toward the base, but sandy and coarser toward the top. In some localities it is dark brown or black with carbonaceous matter especially in the lower strata. The contact between the underlying limestone and the succeeding shale is usually a transition by interbedding of alternately more earthy and more calcareous layers, each parallel or conformable to the preceding one. At isolated points, however, and especially along the eastern margin of the Great Appalachian Valley, there is an unconformity between the shale and the limestone; it is marked by a conglomerate composed of pebbles of limestone and chert in a matrix of sand, and by overlap of thin successive strata of shale and sandstone upon the limestone. The thickness of the shale is very variable. In a line of lenses which ex-

tends from the upper Hudson Valley through the corresponding valleys of Pennsylvania, Maryland, Virginia and Tennessee, it attains a maximum of 3,000 to 4,000 feet. The Massanutten Mountain of Virginia and the Bays Mountains of Tennessee are composed largely of these great thicknesses of shale. A few miles west of this line the shale is but 1,000 feet thick or less.

These several facts of the character, relations and distribution of the shale yield a consistent interpretation of the changes from which they resulted. The constituents are those enduring minerals whose worn particles may be derived from the flood-plains of streams flowing on a lowland, or from erosion of sedimentary rocks. The transition from limey to clayey deposits with alternation of character is what should occur on a shallow sea-bottom off the mouths of muddy rivers, which were engaged in removing their flood-plains. These effects should follow from a general but moderate elevation of land, including a strip of adjacent sea-bottom. The local occurrences of conglomerate derived from the limestone indicate that islands or peninsulas developed in consequence of higher, though limited, uplifts of the sea-bottom. And the accumulation of the shale in lenses of maximum thickness shows that through subsidence along a definite zone there developed a trough which directed currents and gave special conditions of distribution of sediment. Recovering from the subsidence of Cambrian time, which, though prolonged and extensive, had been of moderate depth, Appalachia now rose slowly as a broad lowland mass which was ultimately bounded on the west by a downward bend of the sea-bottom corresponding to the present line of the Great Appalachian Valley. That flexure descended gently beneath deeper water to a trough, from which the sea-bottom rose more gradually westward to a shallow sea or, possibly, a land area, that developed at the close of this epoch or soon thereafter in Western Ohio and Kentucky. This western island is known as the Cincinnati arch.

Thus the broad Cambrian sea retreated from its eastward excursion and became a gulf, occupying Eastern Tennessee, Southern Kentucky, Eastern Ohio, West Virginia, the Valley of Virginia and

Maryland, Pennsylvania and New York, and communicating by a narrow strait or straits with the St. Lawrence Valley. Its waters did not again spread over Appalachia.

THE CHANGE OF LIFE CONDITIONS.

The broad shallows of the Cambrian-Silurian sea had afforded a roomy habitat for a large marine population. As the sea narrowed to a gulf the host was crowded into limited space and competitive conditions became severe.[1] Clear seas became muddy through addition of sediments and the food supply was modified. A great change in living forms followed. Evolution proceeded rapidly, resulting in large faunas with diversified members, and the later or Upper Silurian is accordingly separated from the Lower Silurian or Ordovician by decided differences in the forms of life.

DEVELOPMENT OF COASTAL PLAIN FORMATIONS.

A coastal plain is a stretch of gently sloping land adjacent to a coast. Its slight elevation and insignificant inequalities of surface cause the sea to advance widely upon it or to retreat broadly from its temporary margin in consequence of comparatively slight oscillations of sea-level. The effect of repeated submergence and emergence is to subject sediments which accumulate on a coastal plain alternately to the waves and to the atmosphere. They undergo weathering and washing, and the coarser particles of the harder, less soluble materials survive longest. Thus the coastal plain becomes the storehouse of pebbles and coarse sands of durable rocks. Quartz is very much more durable than most minerals and is far more abundant than any other coarse product of rock-decay, and it is stored from age to age in coastal plains.

Emerging from the retreating Silurian sea, Appalachia presented the gentle slope of a broad coastal plain. While emergence was progressing, rills and rivers, extending their courses to the receding shore, contributed the waste of the plain, which waves worked over

[1] This effect of marine recession is broadly discussed by Chamberlin: see "A Systematic Source of Evolution of Provincial Faunas," Journal of Geology, Vol. III, No. 6, pp. 602-605.

into new deposits. Fluctuations of level, which may have been strongly marked in the sandy and clayey strata of the coastal plain, are faintly recorded in the mass of shale which accumulated where the waters deepened more abruptly, but the coarser detritus was redistributed during succeeding epochs and the detailed record is lost. Nevertheless, the fact of the former existence of a coastal plain is indicated in the quartzose character of some later formations, and recognition of their earlier history serves to explain their concentrated composition.

A REMNANT OF THE SILURIAN COASTAL PLAIN.

Succeeding the great shale formation, which is taken as the last deposit of the Lower Silurian, follow coarser deposits of varied character. In general, they are red sandy shale or red sandstone, or locally, even conglomerates, upon which rests a white sandstone of large grain, sometimes pebbly. The red strata are composed of lime, clay and quartz sands, the particles being coated with red oxide of iron; the overlying white sandstone consists almost wholly of quartz. The contact between the red and white strata is sharp. This sequence is considered to contain some of the materials of the Silurian Coastal Plain and sediment from uplands deposited under varying conditions.

The presence of iron oxide as an important constituent of the red rocks is significant of the chemical dissolution of rocks containing iron minerals, from which iron was carried by streams either in solution or as a fine silt consisting of ferric oxide to the locality where it was deposited as a coating on grains of clay and sand. Students are not agreed as to the conditions essential to this process, but the following explanation may here be offered with special application, following closely the hypotheses suggested by Chamberlin.[1]

The rocks of Appalachia containing available ferriferous minerals were the pre-Cambrian rocks, which had been to a great extent, if not wholly, buried by sediments of the Silurian sea during its eastward migration. But now in consequence of erosion corresponding

[1] Several articles in the Journal of Geology, Chicago, summed up in An Hypothesis of Cause of Glacial Periods, Journal of Geology, Vol. VII, No. 6, pp. 563-568. Sept.-Oct., 1899.

to the accumulation of the lower Silurian shale formations, areas of the pre-Cambrian rocks were laid bare in the higher lands of Appalachia east of the coastal plain. Several conditions combined effectively to decompose and oxidize them. They had already in Cambrian time been superficially disintegrated and probably not eroded down to perfectly fresh rock during the transgression of the shore. While buried under sedimentary beds, the rocks beneath the plane of unconformity were subject to the action of waters which found along that plane an easy course of percolation. Thus, when uncovered, the ferriferous minerals were prepared for dissolution. But more effective conditions followed from uplift and consequent erosion. Valleys being cut in the elevated mass, the level of standing ground-water was lowered and a corresponding volume of rock was affected by atmospheric waters percolating downward. Such waters carry carbonic acid which dissolves, and oxygen which oxidizes many mineral constituents, and among them iron. The process of weathering proceeded more rapidly than that of denudation, and so long as that relation of activities continued the land was deeply mantled with soil and decayed rock, furnishing abundant iron oxide to the sediments removed by streams.

As a supplement to the preceding explanation, a further hypothesis may be stated. It is believed that the deposition of a stratum of limestone is accompanied by the liberation of carbonic acid, which, having been combined with lime as bicarbonate in solution, is set free in the ocean and passes into the atmosphere, while the lime takes the relatively unsoluble form of monocarbonate. When the limestone deposit is extensive and thick, as the Cambrian-Silurian limestone was, the small proportion of carbonic acid in the atmosphere may be notably increased, as has been pointed out by Chamberlin.[1] By this action the atmosphere in mid-Silurian time was probably enriched in carbonic acid, and the rains which fell contained an important proportion of that active solvent. Thus the decomposition of ferriferous minerals proceeded with peculiar energy.

[1] Chamberlin, "The Influence of Great Epochs of Limestone Formation upon the Constitution of the Atmosphere." Journal of Geology, Vol. VI, No. 6, pp. 609-621.

VIEW OF THE WESTERN SLOPE OF WILLS MOUNTAIN IN WILLS VALLEY, NEAR CUMBERLAND.

Two activities appear to have shared in depositing the iron thus provided by rapid disintegration of ferriferous rocks. That part of the iron which was oxidized in the rocks before denudation exposed it, when eroded, became a fine sediment intimately associated with clay, and as such was readily swept to the sea in muddy rivers. Its fineness sufficed to promote a separation from the coarser sands of quartz and undecomposed minerals. Another part of the iron, which was dissolved by carbonic acid and not oxidized in the mass of decomposing rock, entered the underground water circulation and through springs and streams flowed to the sea. It may have been oxidized in part *en route* or in part in the sea, whose surface in play barters with air.

The waters of the gulf on the west had become shallow near the shore as the trough was filled with shale, and perhaps as the general relative uplift of Appalachia spread westward. The deposits were not stirred or sorted by the slight wave action of the shallow water, and the coarser particles remained coated with the fine ferruginous mud.

The white sandstone (in these reports called the Tuscarora) which follows sharply upon the clayey red shale and sandstone differs from them in being thoroughly washed and freed from fine sediment. It is a characteristic deposit of a wave-beaten beach, cleaned and spread by transient currents, frequently with cross-bedding. The ripples which distributed the red muds of the preceding strata were the spent vanguard of waves which broke on the distant margin of the shallows. Slight deepening of the water along that margin, or gentle tilting of the bottom westward, may have sufficed to permit the zone of breakers to advance eastward. In advancing they stirred the surface of the red deposits and redistributed the materials; they built barrier beaches and scoured the sands upon them; and the undertow swept even quite coarse detritus down the slope toward deeper water. As this activity progressed beyond the area of red muds and attacked possibly earlier coastal plain strata and the coarse detritus remaining from the residual mantle, it reached a large volume of quartzose material. The thickness of the white sandstone, 600 to 800 feet, indi-

cates that the source of supply was large, and its coarseness even as far west as Wills Mountain near Cumberland shows that the waves repeatedly swept back and forth over the submarine coastal terrace. The slope of that terrace may be compared with that of the present Atlantic shelf of North America, which descends from the shore seaward at the rate of about 6 feet per mile for 100 miles, and then sinks at the rate of 300 to 700 feet per mile 10,000 feet into the oceanic abyss. The slope on which the white Silurian sands were washed was probably more than 6 feet per mile, but much nearer to that figure than to 300 feet. The massive white sandstone thus formed, which gives to the Narrows in Wills Mountain their picturesque cliffs, is a remnant of the ancient Silurian coastal plain. After millions of years of burial, the sands are again entering the circulation by river and wave to become part of some beach and to record the passing aspect of the Atlantic shore.

THE APPALACHIAN GULF CLOSED AT THE NORTH.

The coastal plain strata which have been described constitute in New York the Oneida and Medina formations, which extend west of the Hudson and south of the Mohawk rivers in such manner as to define approximately the northeastern limit of the Appalachian Gulf at that time. Communication with the St. Lawrence depression was apparently barred by a rising land area and the gulf became a long water body open only at the southern end.

The uplift which thus closed the northeastern outlet of the sea has been described[1] as a mountain-making disturbance, which produced the Taconic mountain range. The elevation which now constitutes that range is of later date than the Paleozoic era itself, as has been shown by studies of the physiography of New England,[2] and the mountain-making of Silurian time can only be judged by the disturbances of the rocks and the volume of resulting sediments. The disturbances of which the Silurian rocks now exhibit the effects were intense and were probably not accomplished in a single episode.

[1] Manual of Geology, J. D. Dana, 4th Edition, p. 527.

[2] The Physical Geography of New England, Wm. M. Davis, p. 269 et seq. in Physiography of the United States, Am. Book Co., 1896.

The date or dates of their occurrence are Silurian or later. The more effective movements may have been Carboniferous. In certain localities there is, however, a discordance between the attitude of earlier Silurian strata and those of the coastal plain episode which has just been described, and the earlier sediments had evidently been disturbed. A distinct elevation of New England and adjacent areas is indicated in the deposits of the Oneida, Medina and Clinton epochs, but it would appear that the uplift was not of conspicuous mountainous height as the volume of sediments contributed to the Appalachian Gulf from erosion of the area was moderate.

Shallow Waters and Lowlands; Upper Silurian and Early Devonian.

OSCILLATIONS OF RELIEF OF LAND AND DEPTH OF WATER.

Conditions of climate and rock-exposure continued to be favorable to the erosion of clayey and ferruginous sediments, as they had been before the white sandstone was spread. The waters of which it had become the bottom were shallow and swept by tidal currents, which may probably have been strong in the restricted gulf. The bottom was slowly subsiding, while strata were rapidly accumulating, and the depth of water changed from time to time. Gray and red and olive-green shales and sandstones, which vary greatly in color and texture from layer to layer and place to place, record the conditions. They attain a maximum thickness of 2,600 feet in Pennsylvania, and elsewhere are 1,000 feet or more thick. Occasional calcareous beds, especially rich in iron and known as the Clinton iron-ores, mark episodes of peculiar conditions whose character, widespread occurrence and recurrence at intervals have not been explained. Although oxidized at the present outcrop the iron in unweathered beds occurs as carbonate. The deposits are therefore of a chemical nature.

The very moderate oscillations of relative level of land and sea, which sufficed to contribute and distribute the sediments of Silurian time, had not involved any conspicuous mountain growth. Whatever hills may have diversified the Silurian landscape of Appalachia were carved by rain and streams from broad low uplifts. The plains

that now stretch from the Mississippi to the Rocky Mountain Front may present a similar relief, especially where vegetation is absent, as in the Bad Lands. In contributing the waste which forms the Clinton sequence, Appalachia had again sunk to a low featureless plain. Consequently when the gulf deepened over Ohio and western New York, little or no sediment clouded its waters, in whose clearness corals flourished and, with other invertebrate organisms, built up the Niagara limestone.

During the succeeding episode the waters of the gulf along its northeastern and northern shores again became shallow, so that calcareous muds accumulated. The corresponding tide-flats repeatedly afforded conditions for evaporation of sea-water from extensive pools, in which salt crystallized in beds of considerable thickness. Again deepening, the waters permitted the accumulation of the calcareous sediments which form the Helderberg limestone.

As the Appalachian Valley from New York southward and the zone extending a hundred miles to the west, was the belt over which the shore of the gulf fluctuated during the upper Silurian, the record of that time was there made in detail, and the broader aspects may be lost in following the minor episodes. But the white mark which the waves built at the beginning of the upper Silurian, the Tuscarora sandstone, was in a measure duplicated by them in the transition to the next succeeding period, the Devonian. The second mark is the Oriskany sandstone.

The Oriskany is composed of clean quartz grains and pebbles in a calcareous cement; locally it is limestone, and elsewhere it is quite purely quartzose. Like the Tuscarora sands, those of the Oriskany had been wave-beaten and sorted on the coast during preceding epochs, where they were stored in the zone of beach development so long as the seaward slope was nearly level. When that slope grew steeper, as their distribution demonstrates, they were swept out into the area where calcareous deposits were still accumulating.

The Tuscarora sands were spread beneath a sea which was pushing its shore eastward across broad tide-flats. The Oriskany sands, on the contrary, were deposited west of a shore which was proceeding

westward. The waves which delivered them to the sea passed westward over the resulting stratum, which was added to the land. It was exposed at a very low level and gentle slope, but it is generally more or less eroded on its upper surface.

The continent of Appalachia has thus far been discussed as a whole without division into northern and southern provinces, but the strata are not strictly uniform along the entire coast from New York to Alabama, and the detailed interpretation would vary if written for Georgia from that which would be logical for Maryland. The episodes of oscillation of sea-level, which permitted the spreading of upper Silurian sediments succeeding those of the Clinton formation, did not extend to eastern Tennessee and Georgia. After the earlier events of the upper Silurian, which developed the ferruginous Rockwood formation of the South, the shore stretched through central Tennessee and thence westward. The region to the east and south was a lowland. During the Oriskany epoch, brownish sandstones were washed over its margin as far east as northern Georgia, but the subsequent gentle elevation of Appalachia sufficed to expose the stratum to erosion, and much of it was removed.

The student of physical changes finds no important episode of mountain growth or continental development to define the close of the Silurian period and the beginning of the Devonian. The record describes Appalachia as a monotonous lowland now rising a little higher, now not so high, above the fluctuating coast of marsh and beach and tide-flat. But the evolution of organisms ran its course and extinction and migration repeatedly changed the population of the Appalachian sea. Before the Oriskany epoch it had assumed those aspects which are considered to characterize the Devonian period.

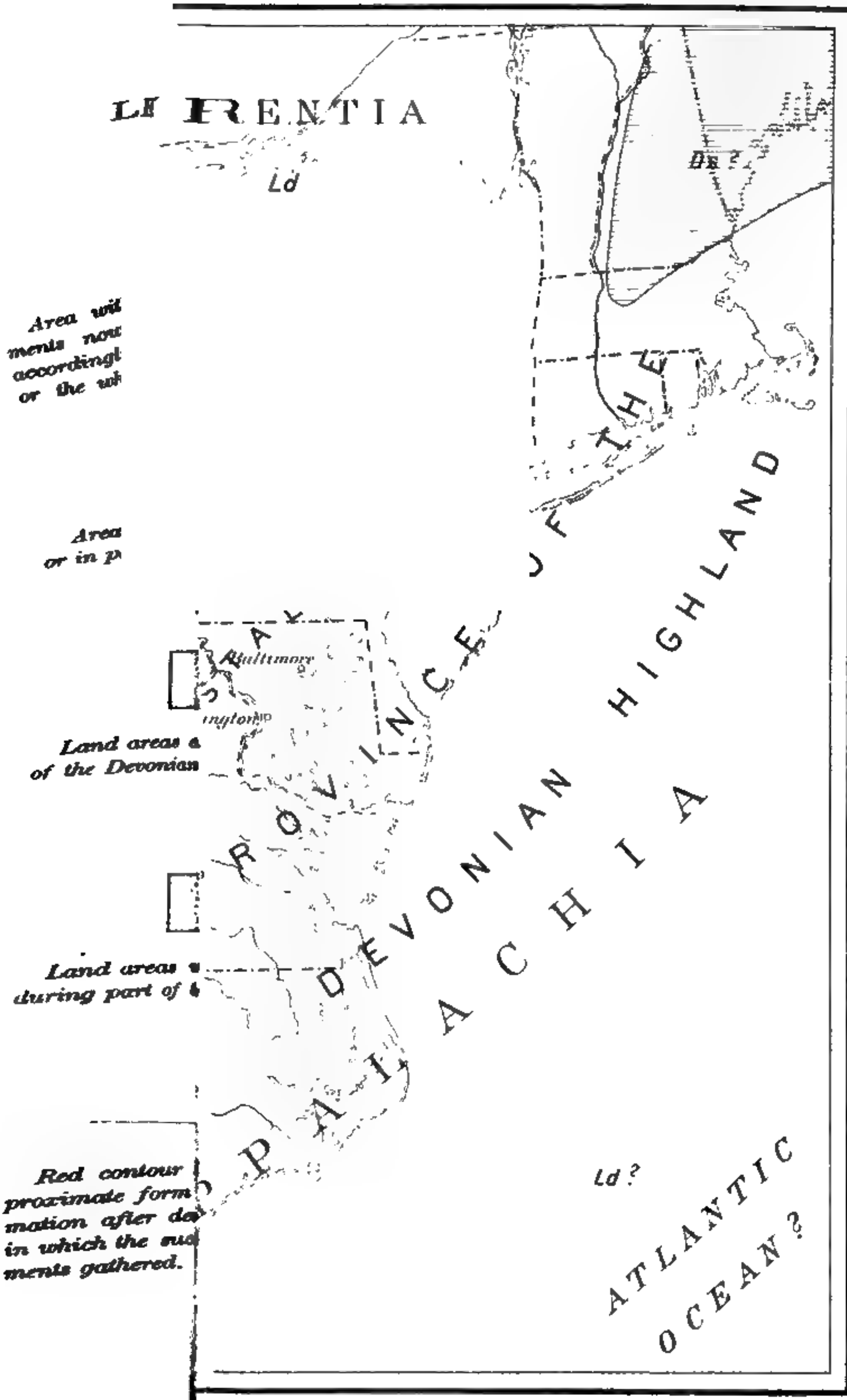
THE WIDE EXTENT OF THE DEVONIAN LOWLAND.

During the episode of erosion of the low-lying surface of the Oriskany sandstone, the adjacent gulf on the west and northwest supported a rich fauna of corals which built up a limestone known as the Corniferous. In significance as to physical conditions it is sim-

ilar to the Niagara limestone, the waters having been clear and warm, a congenial habitat for coralline growths. The absence of mechanical sediment bears testimony to the fact that the waste of the low plains of Appalachia was being stored in broad marshes along shore, where aquatic vegetation may have aided to filter the currents flowing seaward.

Succeeding the Corniferous limestone and overlapping upon the eroded surface of the Oriskany eastward as far as the central line of the great Appalachian Valley is the black shale, in these reports called the Romney formation, and generally known as the Hamilton group. It is a fine-grained, calcareous or sandy mud-rock, black or dark brown with organic matter, and often bituminous. In Alabama it is but a few feet thick and thins out to a feather edge to the south and east; in Maryland it attains a thickness of 1,400-1,500 feet, and thence grows thinner toward its northern outcrops in New York, where the thickness is about 1,200 feet.

Only the great Cambrian-Silurian limestone exceeds this bed of black shale in uniformity and extent of occurrence. Its distribution corresponds to an eastward and southeastward migration of the coast from the shore of the Corniferous gulf over the low marshes of Appalachia. The submergence brought within range of the waves quantities of vegetation and the sediment of estuaries, while the warm shallows afforded a habitat for algæ and a fauna that found the muddy waters congenial. The duration of the epoch is not to be measured by the thickness of its sediments; not only do they vary from 15 feet or less to 1,500 feet, but the thin layer of black shale in Alabama and Georgia appears to be all that accumulated in that region until after succeeding Devonian strata in Pennsylvania had attained a total thickness of 10,000 feet. There is perhaps nowhere a more striking illustration of the intimate relation between the rate of sedimentary accumulation and the topographic phase of the adjacent land. The thin stratum of black mud which, during a long epoch gathered in shallow waters, without material addition of other sediments or removal of its own insignificant layer, demonstrates the stability of a sea-level plain. Time passed unrecorded there. Ten



Bailey Willis
1899

thousand feet of sediment, during the same epoch accumulating in the neighboring sea, represent a transient height of land and rivers flowing from it. Thereby events were voluminously recorded.

The general distribution of the black muds of the Hamilton was the last episode of the series of gentle oscillations of sea-level which had varied the sequence of events during all later Silurian and earlier Devonian time. The monotony of the movement was then interrupted.

The Devonian Highlands.

CHARACTER AND VOLUME OF SEDIMENTS.

Succeeding the black Hamilton shales from New York to southern Virginia occurs a great volume of sandy shale and argillaceous sandstone comprising the Jennings and Hampshire formations of Maryland or the Chemung and Catskill of New York. It is divisible into several formations according to the composition, color, texture and included fauna of successive beds, but it is a unit in so far as it represents physical conditions of land and sea which were favorable to rapid erosion and deposition. The strata are thin, rapidly alternating in character, current-bedded, and ripple-marked. They vary in color from buff or gray through shades of green and olive to dark purple or deep red tints. Their constituents are clay, fine and coarse sand, occasional quartz pebbles, and in some strata abundant scales of mica. Oxide of iron is an important constituent, especially of the higher beds to which it gives their preponderantly red color.

The thickness of the mass varies in such manner that the deposit has somewhat the form of the internal cast of a great mussel shell. The thin edge of the cast extends from Lake Erie southward through Ohio and eastern Kentucky to eastern Tennessee, where one end of the mass is. Thence the hinge-line of the mussel-shaped form runs northeast to New York, whence the thin edge rounds westward. The upper surface of this cast may be considered to be flat and the under surface curved to the hollow of the shell, which is deepest along the hinge-line. The dimensions of this form are: Width from Washington county, Maryland, to northwestern Ohio, 300 miles;

length from northeastern Tennessee to Albany, New York, 700 miles; the greatest thickness in Schuylkill county, Pennsylvania, over 10,000 feet. The area covered by it exceeds 100,000 square miles. If this mass, with approximately the dimensions with which it was deposited in the sea, could be restored upon a sea-level plain of Appalachia, it would constitute a mountain range closely resembling in height, extent and mass the Sierra Nevada of California. Its position, with reference to the ancient coast, would also be similar to that of the modern mountain range with reference to the Pacific. These sediments are the waste of a Devonian highland which grew and suffered erosion during that period.

TOPOGRAPHY OF THE HIGHLANDS.

The preceding comparison may serve to give a crude estimate of the magnitude of the Devonian mountains, but it does not follow that the ancient range resembled the Sierra in topographic character. If the former rose more slowly than the latter it may always have been of gentler aspect and never so elevated. Their nearest genetic likeness lies in the fact that both ranges developed where previously a plain extended.

The topography of the Devonian highlands can be conjectured only from the character of the sediments. Their constituents are all the product of thorough chemical decomposition of siliceous crystalline rocks; they are coarse of grain and unassorted. Particles, light and heavy, coarse and fine, are intimately mingled. The general disintegration of the original rocks to the texture of sand and clay indicates deep accumulation of soil, as in the Appalachian Mountains of the present day where weathering of the crystalline rocks very generally proceeds faster than the removal of the products of rock-decay. The dark red color of many strata is due to oxidation of iron from deeply decayed ferriferous rocks. The Devonian highlands probably exhibited rounded forms of hill and valley, and thus may be contrasted with those ranges which present savage precipitous profiles. The presence of mica and of heavy minerals not easily decomposed indicates that the sediment was derived directly from

the decaying rocks; it had not been stored in flood-plains, coastal plains, or estuaries during previous ages. Its immense volume suggests large streams whose turbid floods coursed swiftly to the sea.

The unassorted mingling of sandy and clayey particles is a result of rapid deposition at the mouths of muddy streams in opposition to waves which are too weak to sort and distribute the volume of sediment. This is a condition of delta-building. In the Devonian sediments as they are now exposed to view the typical contour or profile of any delta may not be observable, but the stratification is not less significant. The frequent and irregular interbedding of coarse sands, sandy clays and clays; the cross-stratified beds, the ripple-marked and sun-cracked mud surfaces, the channels scoured by transient streams, all prove the abundance of the sediments, the shifting conditions of deposition, the irregularity of currents, the wide expanses of tide-flats and shallow waters, and the weakness of the waves.

THE CHARACTER OF DEVONIAN DEFORMATION.

Shallow waters prevailed over an area several hundred miles in extent along the coast and one hundred to one hundred and fifty miles wide from the shore westward; and during the accumulation of from 6,000 to 10,000 feet of strata the upper surface of the deposit was repeatedly just at sea-level. These facts are inconsistent with stability of the sea-bottom. The water was now deeper, then shallower; it withdrew, and as often returned over many square miles of flats. The floods and low waters of tributary rivers and the ebb and flood of tides, together with the gathering sediment, may be considered adequate to explain many minor variations, but the range of these oscillations across a hundred miles or more is evidence of those crustal movements which cause changes of the sea-level. These movements were very slight in vertical amount, but very frequent; and the sum of downward movements was greatly in excess of those upward, so that the total result was a deep subsidence. Since the surface of the sediments accumulated in the depression was repeatedly near sea-level, the deposits obviously filled the basin as it developed, but the completeness of filling was intermittent, the

water being now deeper, now shallower, as the rates of sedimentation and vertical oscillation of the shore zone varied relatively.

Before the deposition of these later Devonian sediments, the sea-bottom on which the black muds were spread presented a gentle, even slope westward, and the adjacent plain of Appalachia extended that slope eastward. During the deposition of the succeeding Devonian sediments, the submarine plain was tilted down eastward, so that it descended from Ohio to Maryland 10,000 feet in 300 miles. The terrestrial plain, on the other hand, at a long distance from the sea, was elevated several thousand feet and given a westward inclination. Thus a depression and an uplift were simultaneously developed in opposition one to the other, probably with a wide coastal plain between, and the hollow was filled by the highland, the material being transferred by that activity of erosion and sedimentation which followed the movements. The original cause of those movements and the conditions controlling them form interesting subjects for speculation.

CLOSE OF THE DEVONIAN PERIOD.

Again the student of Appalachian physical changes finds the end of the great period paleontologically marked at an epoch which is part of an apparently continuous sequence of events. There is no evidence of an interruption in the sedimentary record which might correspond to an hiatus, nor of any continental or provincial catastrophe to close the Devonian or open the Carboniferous chapter. But in all probability the change in organisms marks a lapse of time which was long in proportion to the thickness of strata deposited toward the close of the Devonian.

It has been stated that in Georgia and Alabama Devonian strata are very thin, and the fact has been explained as a consequence of the very slight elevation of the adjacent land. When the northeastern Devonian uplift had culminated and the rate of erosion exceeded that of elevation, the highland entered upon the later stages of mature topography marked by minutely branching valleys and ridges, and progressed toward the aspect of an aged landscape, a lowland. The episode of maximum waste is that of maturity, and

during the succeeding stages of topographic development the detritus removed grows constantly less and less until it almost fails. The rate of accumulation of sediments decreases correspondingly. Thus the latest Devonian strata may probably represent much longer time than those deposited during the maximum development of the highlands. The result of the activity of erosion was the expansion of a generally low but not featureless landscape on the site of the Devonian highlands.

Appalachia During the Early Carboniferous.

SOURCE OF THE POCONO SANDS.

The shallowness of the Devonian sea has been emphasized in the preceding paragraphs, because it is one of the most striking and significant facts of the corresponding episodes. But from time to time waters prevailed of such depths that waves played energetically along the shore of Appalachia, and accomplished the sorting of a large volume of material. The muds sorted out were added to the greater mass of river sediments; the clean sands and pebbles were left on the broad coastal plain of Appalachia over which the waves migrated. In general, during the transgressions of the sea, the place of deposit of the sands was inland, beyond the mouths of estuaries and the belt of tide-flats which were bared during recessions, but the slope of the off-shore plain was too low for the distribution of coarser detritus. Here and there through the Devonian muds occur limited lenses of peculiarly coarse sandstone or conglomerate, the fringes of the extensive coastal plain formations spread far to the east.

When, after the close of Devonian time, the continental landscape had taken on the monotony of an undulating plain, there occurred a slight submergence accompanied by tilting of the plain toward the west. Rolling across the slowly deepening waters, waves broke on the coastal plain, stirred the incoherent sands, and delivered to the undertow all that was not too coarse. Swept out and mingled with shore drift of plants and with more or less mud from the inactive rivers, the sands and pebbles formed a bed of sandstone and conglomerate generally known as the Pocono sandstone.

Along the eastern outcrop in Maryland, Pennsylvania and New York, the Pocono sandstone varies from 400 to 2,100 feet in thickness. Westward it thins rapidly, and, by interbedding with red and gray muddy deposits, passes into shales in Ohio. Southwestward it underlies and thins out beneath the limestone, which represents the early Carboniferous deposits of the widely extended interior sea of the West.

THE EARLY CARBONIFEROUS LOWLANDS.

The Carboniferous limestone, like the great Cambrian-Silurian limestone, is a formation which was related to a general condition prevailing over the surrounding lands. Of great thickness and massiveness in the Rocky Mountains, the Central States, and the southern district of the Appalachian province, it records the general development of low-lying plains. But northeastern Appalachia, though low along the shore during the Pocono episode, continued to contribute much sediment from the hills of the interior, and rising gradually for a time, renewed in a moderate degree the conditions which existed during the uplift of the Devonian highlands.

THE EARLY CARBONIFEROUS HIGHLANDS.

Where not covered by the limestone, the Pocono sandstone is succeeded by red and greenish sandy shales known as the Mauch Chunk formation. The beds are ripple-marked and current-bedded throughout. Their thickness is greatest along the eastern side of the Southern Anthracite field, where it exceeds 2,000 feet. The red shales thin westward and southwestward and grade into corresponding beds of limestone. Thus it appears that the Mauch Chunk, like the great red formation of the Devonian, is a deposit limited to the northeastern portion of the Appalachian gulf, and that it represents a height of land which was elevated, eroded, and distributed in the Carboniferous sea. Elsewhere the bordering lands about that sea were low, and mechanical sediment failed, while calcareous sediment, largely and perhaps wholly of organic origin, accumulated.

The strata corresponding to this highland are not as voluminous as those which represent the Devonian mountains, and it may be inferred that the uplift was correspondingly smaller. The movement

was, however, identical in character; the trough which contained the Devonian sediments gradually deepened more than 2,000 feet and was continuously filled by the Mauch Chunk strata. The eastern land was elevated sufficiently to rejuvenate the rivers which reassumed the character of vigorous turbid streams.

Development of the Carboniferous Coastal Plain.

NATURE OF THE SEDIMENTS.

The later episodes of the Carboniferous period, during which the coal deposits accumulated and the Appalachian gulf was filled, comprised a very complex sequence of events. The effects were not uniform throughout the province. The strata are irregular and the succession varies greatly from place to place. It is not possible in this brief account to discuss any section in detail, but only to give an explanation of general conditions, which may correspond fairly well with the facts.

Quartz is the predominant constituent of the strata. As pebbles and in coarse or fine grains it constitutes nearly the whole of many conglomerate and sandstone beds, and it often forms the greater part of strata, whose fine texture causes them to be classed as shale or clay-rock. In so far as they are not quartzose, the strata are of clay. Iron occurs as an incidental constituent in small proportion throughout the series and as carbonate in thin beds, but the red color so conspicuous in the preceding Devonian and Mauch Chunk strata is wanting. Decomposed granitic minerals, such as feldspar, occur in small proportion in sandstones. The coal beds are fossil vegetation. They consist chiefly of carbon derived by the agency of plants from carbonic acid of the atmosphere, and stored as carbon and as hydrocarbons. The plants grew luxuriantly in extensive marshes.

In the proportion of quartz they contain many of the conglomerates and sandstones resemble the Tuscarora, the Oriskany, and the Pocono Coastal Plain formations, but in coarseness the conglomerates, especially the lowest or Pottsville conglomerates, greatly exceed any previous deposit.

The beds are generally cross-stratified, irregularly bedded as by swift and transient currents, interbedded with marsh deposits, locally

eroded, or overlapped, an earlier by a later group of strata. These are evidences of repeated variations in depth of water and of the activity of waves and strong currents along shifting shores.

The thickness of strata above the Mauch Chunk shale varies from 2,000 to 4,000 feet along the eastern outcrop, and the equivalent series above the limestone toward the west and south thins to 1,000 feet or less. In the Appalachian gulf east of the Cincinnati uplift, the strata cover approximately 80,000 square miles. The volume of sand and clay is not equivalent to a high mountain mass over the same area of Appalachia. But although the volume of sediments as it was deposited is not large as compared with a mountain range, the mass of rock from which it was derived was of great magnitude. Quartz, the predominant constituent of these Carboniferous strata, is a comparatively small component part in a free state of the pre-Cambrian schists and granites, yet it was no doubt produced by their decomposition and by the disintegration of the quartz veins by which they are cut. The proportion of free quartz in the old rocks is not definitely known, but if it be assumed to be as much as one-third, a highland which should supply the Carboniferous sandstones from a base of 80,000 square miles, should rise to a crest of 6,000 to 12,000 feet. Had such a highland existed in Carboniferous time, the deposits resulting directly from its destruction should include not only the quartzose, but also the more voluminous clayey formations. That the quartz only is represented may be explained by prolonged storage and concentration of that durable mineral in a coastal plain as was stated on page 52. In that event the clayey deposits corresponding to this volume of quartz should be looked for in earlier formations of the Carboniferous or even of the Devonian period. The clay was then widely distributed, perhaps far from the shore where the quartz sands and pebbles were being washed and re-washed, until they, too, were buried in strata.

WESTWARD TRANSFER OF THE COASTAL PLAIN.

The Pottsville conglomerate, which succeeds the Mauch Chunk shale, is a remarkably coarse deposit. Quartz pebbles 1 to 3 inches

in diameter constitute thick strata along the southeastern outcrops in Pennsylvania and much larger pebbles occur. Fifty to one hundred miles farther west the formation is represented by pebble beds, in which the pebbles may attain a diameter of an inch, and by coarse sands. These coarse, clean quartzose deposits lie immediately upon the muds of the Mauch Chunk formation, and thin layers of the mud are sharply interstratified with the lower conglomerate and sandstone beds. The marked contrast in the sediments is significant of a change in depth and slope of the sea-bottom. Tide-flats of the Mauch Chunk epoch were submerged, and their practically level surface was in part replaced by one having a decided seaward inclination.

These conditions of deposition of the coarse Pottsville sediments may reasonably be stated as follows: Gentle subsidence of the sea-bottom sufficed to establish a moderate depth of water over a wide area previously shallow. As the conditions became favorable for them, strong currents circulated. They washed the surface of the Mauch Chunk deposits, scouring off the unconsolidated mud and filling depressions. They checked the development of deltas by sweeping the river mud away to greater depths. Rising relatively to the coastal plain, the sea flooded low valleys, producing estuaries. Between these stretched low peninsulas composed in part, at least, of coarse and fine quartzose coastal plain deposits. Waves, favored by the depth of water, attacked the headlands, and cutting across their ends, built out spits of gravel and sand, which they extended across the mouths of estuaries. Here waves and littoral currents, both most effective during great storms, contended against the rivers, which carried most sediment during occasional floods, and here accordingly the quartzose coarse deposits of the former alternated irregularly with the muddy strata spread by the latter. The wave-built features along the coast assumed the profile of shore terraces, sloping from the beach gently or steeply, according to the grain of the material and the strength of the action, as far out as the waves could agitate and roll the detritus, and thence more steeply into the deeper water.

The width of terraces which may be built by waves at a constant relation to sea-level is narrowly limited by the character of the material and the strength of the waves; but along a shore washed by strong currents there is a reaction between the embankment and the current as a result of which the deposit is extended. As the terrace is built out it encroaches upon the course of the current which becomes accelerated by being confined. The encroachment may continue until the acceleration is sufficient to enable the current to scour the face and so prevent further widening. Whatever material, within the transporting power of the current, the waves thereafter deliver across the terrace is carried along shore and deposited as the current slackens in deeper water. This process is continuous so long as the supply of sand holds out, and the activity of a current may thus result in depositing abreast of any section of the coast a great volume of shore drift derived from an adjacent section. Thus result material differences in thickness of deposits along a coast.

During progressive subsidence of the sea-bottom the supply of detritus from the coastal plain of Appalachia was continued. The downward movement may have been to a certain extent shared by the coastal plain; then the shore and its attendant terrace advanced eastward and the shore currents scoured the surface of each previously wave-built structure, redistributing the sands and gravels of which these were composed. During the greater part of the subsidence, however, the movement was probably not shared by the coastal plain of Appalachia. The maximum thickness of the Pottsville formation in eastern Pennsylvania is 1,200 feet, and the surface of the Mauch Chunk subsided to that extent during the Pottsville epoch. Had the coastal plain been equally depressed the sea would have transgressed far to the eastward and the accumulation of coarse detritus would not have been concentrated to so great a thickness in a narrow zone. The Appalachian plain was probably raised and tilted westward, delivering the coarse and fine land-waste to a shore which did not migrate far east of a certain limit.

The gathering of a great thickness of gravel and sand in a narrow zone in the presence of waves and currents was accompanied by a

corresponding widening of the deposit on the sea-bottom. To estimate the width which the deposit might attain during a simple episode of submergence, reference may again be made to the submarine slopes on the Atlantic shelf. Off the south shore of Long Island the sandy bottom descends 45 to 60 feet in the first mile from the beach, and for 5 miles out at the rate of only 15 to 20 feet per mile. Off Cape Hatteras, east of the outer Diamond Shoal, the bank which lies 15 to 20 fathoms below the water has a greatest slope of 30 feet in one-quarter of a mile, or 120 feet to the mile. The materials of this bank are pebbles and broken shell. If the slope of the Pottsville formation was constructed under similar conditions, the width of the base on a level west of the zone of maximum thickness would not have exceeded twenty miles. In fact, the extent of the coarse pebbly strata west of the maximum thickness considerably exceeds a hundred miles. Unless improbable assumptions as to the strength of currents be made, it is apparent from the above comparison that a simple episode of submergence is not adequate to afford the conditions essential to spreading so widely this conglomeritic formation.

The Pottsville formation affords much other evidence of the complexity of conditions attending its development. For example, among the variable strata of which its mass is composed, are coal beds. Some of these are of driftwood buried in current-bedded sand, but others are evenly laid marsh or lagoon accumulations, and though thin, they record an episode when some portion of the sands had temporarily emerged from the sea. The growth of vegetation which formed the coal took place after the surface had passed from submarine to land condition, that is, after the line of breaking waves had retreated across it. During such retreat the shore lay along the generally uniform slope of the latest stratum of sand and gravel, which was thus subjected to wave erosion. The efficiency of the waves depended upon the depth near shore and that of the transporting currents upon the relative steepness of the slope. The deeper the water inshore, the steeper the immediate slope away from the shore; and, accordingly, the more efficient the waves in eroding the

beach, the more favorable the conditions of transportation. By this activity coarse sediments may probably have been swept over a wider expanse than that on which they might accumulate during a simple submergence. The movements did not necessarily include an episode favorable to accumulation of coaly material, but may have occurred with scarcely perceptible evidence of rising and sinking, yet it is by repetitions of submergence and emergence, probably, that the gravel and sand delivered from the coastal plain of Appalachia formed the very extensive Pottsville deposits.

The above described process of distribution of coarse detritus over a wide area involves the migration of a relatively steep facet in the slope of the coastal plain and submarine shelf. This facet must migrate in a plane constantly near sea-level, and be limited above by the widening or narrowing gentler slope of the coastal plain, and bounded below by the even more gradual incline of the relatively narrowing or widening submarine shelf. These limiting conditions are suggested on the one hand by the inactivity of atmospheric erosion, which remains relatively unimportant during the migrations, and, on the other hand, by the efficiency of scouring currents which, on passing into deeper water, would fail to move coarse material. The amount of vertical movement during any single episode of submergence or emergence is very slight. The maximum depth of water indicated by the effectiveness of currents is probably less than 100 feet, and the elevation of the coastal plain, which is consistent with ineffective erosion and the accumulation of marsh mud, is practically nil.

LAGOON AND MARSH DEPOSITS.

The Pottsville formation consists in large part of coarse deposits, but by no means exclusively. Throughout the New River district of West Virginia and further to the west and south, it contains much fine sandstone and shale with several important coal beds, and thus resembles the productive coal measures which, in the central Appalachian coal fields, formed during succeeding epochs. In strong contrast to the sandstones and conglomerates—deposits of swift-moving waves or currents—are coal beds which accumulated in the

quiet of marshes and lagoons. And scarcely less anomalous appears the intimate interbedding of fine shale, containing numerous remains of land plants and apparently deposited in fresh water, with the coarser sediments. Still another characteristic of the Pottsville, and of succeeding Carboniferous formations in general, is the lenticular form of many deposits, in consequence of which any one bed of sandstone, shale, or coal thins out and is replaced in its own horizon by a deposit of different texture. The significance of these peculiar relations is that the bottom of the open waters and the surface of the land were very near the same level, the waters being shallow and the lands being very low, as has already been stated. And, further, the barriers dividing the sea from the lagoons and swamps of the lowlands were sinuous and shifting. They were barrier-beaches built by shore currents and waves across shallows, or mudbanks accumulated at the mouths of streams, or even nothing more than marginal thickets of rank tropical plants, differing in flora but similar in density to those which now fringe the coasts of Central and South America along the Caribbean. The interior sea shallowed till it became in great part a tropical swamp, composed of irregular morasses, lakes and estuaries. These features were modified at intervals by river floods. Again the surface was more deeply submerged in consequence of slight subsidence, and swift currents of estuaries or marine waters swept in coarse quartzose sediments.

LATER CARBONIFEROUS CONDITIONS.

The deposition of the Pottsville formation was succeeded by many varied sediments which gathered in the Gulf of Appalachia during the later epochs of the Carboniferous era. Some of the strata are sandstones resembling the Pottsville and record an abundant source of quartzose sands and the appropriate conditions of distribution. Other strata are of shale or coal. They are generally of lagoon and marsh origin in the eastern and southern part of the basin, but toward the west and northwest extensive and regular deposits of shale and numerous layers of impure limestone indicate that marine conditions returned frequently in alternation with those of the low coastal flats.

In the marine area the movements were gentle vertical oscillations, according to which the sea-bottom now emerged to just above sea-level and again subsided to depths of 100 feet or more. As sediments accumulated to thicknesses of several thousand feet upon the Mauch Chunk shale, the sum of subsidences was, on the whole, that much greater than the sum of emergences. According to the thickness of sediments, the gross subsidence was also much greater in the eastern part of the sea, along the coast of Appalachia, than it was in the region corresponding to the Mississippi Valley.

During these oscillations of the sea-bottom, the Appalachian land rose slowly and probably intermittently, and not to any great height. The Carboniferous strata record no such mountain range as that which grew in Devonian time, yet the total Carboniferous rise of Appalachia was probably equivalent to a highland of 1,000 to 3,000 feet, and would have resulted in sediments significant of decided elevation had the uplift proceeded more energetically.

In general the gentle movements of land and sea-bottom determined corresponding activities of erosion and sedimentation, such that the broad coastal plain of Appalachia migrated from the zone it had occupied during Devonian time far to the west. Where the shore stood during any particular episode is a question of detailed evidence which may sometimes fail to be conclusive, but there is no doubt that it passed from a position in eastern Pennsylvania and central Maryland and Virginia westward to the Mississippi Valley.

At the end of the activity the Gulf of Appalachia was filled. No further general subsidence of its basin occurred, and the accumulation of marine sediments in that region ceased. Therewith the record of Paleozoic sedimentary history came to a close.

PHASES OF APPALACHIAN DEFORMATION.

How Rocks May Flow.

THE NATURE OF SOLID ROCKS.

Rocks consist of crystals or of grains bound together, usually in a matrix of finer texture which may itself be crystalline or amorphous.

The crystals, grains, and matrix are thought to be composed of infinitesimally small bodies, called molecules, the smallest into which they might be divided. The molecules are drawn together by mutual attractions and resist up to a certain strain any stress which tends to change their relations. This resistance to change of form exists in liquids and gases to a certain extent, but it is most marked in solids, which it characterizes. Thus solid rock may be defined as any rock which strongly resists change of form.

The resistance which solid rock offers to change of form may be called *viscosity*. In this sense a viscous substance is the opposite of a mobile substance. Steel is more viscous than lead, and lead is more viscous than wax. Of the three, the viscosity of steel is highest, the substances being considered in the usual cold solid state.

MAXWELL'S THEORY OF VISCOSITY.

Viscosity, or the resistance to change of form[1] in any solid or viscous fluid, is conceived to be due to the effort made by molecules or groups of molecules to maintain definite relations in a certain configuration. When a solid is subjected to a stress the forces determining the relations of the molecules are affected and those relations may be so modified that all the configurations become unstable, that is, they undergo repeated rearrangement. The solid then passes into the condition of a viscous fluid and this condition may be maintained by an adequate force so long as the solid mass continues whole.

The essential condition of viscous movement is that the molecules or groups of molecules in passing from one unstable configuration to another shall not separate from one another so far as to pass beyond the range of their mutual attractions. When they do the solid breaks or crushes.

If this theory of viscosity and its application to solids under stress be correct, it follows that a solid may change form either by flowing or by crushing. The distinction between the two modes of change depends upon the spaces by which the molecules or particles

[1] Maxwell, Encyclop. Brit., 9th Ed., 1876, Vol. 6, p. 311. Theory of viscosity, Quoted in Bull. 73, U. S. G. S., p. 77. Barus, The Viscosity of solids.

of the body may become separated during the movement. If these spaces exceed the distances within which molecular attractions operate, the solid crushes. If the spaces remain always such that molecular attractions are constantly maintained, the solid flows. Rocks at the surface of the earth are crushed by a sufficient force, because they are free to expand by developing spaces so wide that the separated fragments fall apart. If any rock were confined by a sufficient pressure from all directions and then subjected to a crushing force, it would flow. These conditions have been realized experimentally by Professor Frank D. Adams of Montreal, by whom marble has been forced to flow; and in the earth's crust the pressures which result from the weight of rocks establish at a moderate depth the confinement necessary for flowing. The following considerations may make this plainer.

As the weight of any building rests upon its foundation, so the weight of any rock-mass of the earth's crust rests upon subjacent rock. At a depth of a mile a horizontal section a foot square supports a column of rock a foot square and a mile high, and so also for any other depth. As this statement is true for each layer of the earth's crust, at the surface and below it, it follows that the pressure due solely to weight increases from the surface downward; and as the attraction of gravity also increases in the same direction to a certain depth, the growth of this pressure is more than proportional to the depth below the surface. It is not necessary here to enter into the mathematical discussion of the relations of gravity, density and pressure, but the following table gives the figures according to the Laplacian hypothesis, as calculated by Mr. R. S. Woodward.

Van Hise[1] has shown by careful estimates that the pressure due to weight is sufficient to cause all rocks to flow at a depth of 10,000 meters or about 6 miles below the surface, and that above that zone of flow the crust may be considered to consist of the outermost zone in which all rocks break or crush, and an intermediate zone in which weaker rocks flow and stronger rocks break.

[1] Principles of Pre-Cambrian Geology, 16th Ann. Rept., U. S. G. S., pp. 589-603.

VARIATION OF TERRESTRIAL DENSITY, GRAVITY, AND PRESSURE, ACCORDING TO THE LAPLACIAN LAW.

By R. S. Woodward. 1890.

Depth in miles.	Density.	Acceleration of gravity.	Pressure in atmospheres.	Pressure in pounds per square inch.
0	2.75	1.0000g	1	15
1	....	......	400	6,000
2	....	......	800	12,000
3	....	......	1,210	18,150
4	....	......	1,620	24,300
5	2.76	1.0006g	2,020	30,300
10	2.78	1.0012g	4,200	63,000
15	2.79	1.0018g	6,390	95,850
20	2.81	1.0024g	8,600	129,000
50	2.89	1.0060g	22,000	330,000
100	3.03	1.0116g	45,300	679,500
500	4.18	1.0379g	236,000	3,540,000
560	4.36	1.0389g	318,000	4,770,000
610	4.50	1.0392g[1]	354,000	5,310,000
660	4.65	1.0389g	391,000	5,865,000
1,000	5.63	1.0225g	672,000	10,080,000
2,000	8.28	0.8312g	1,700,000	25,500,000
3,000	10.12	0.4567g	2,640,000	39,600,000
3,959	10.74	0.0000g	3,000,000	45,000,000

The phenomena of viscous flow of rocks involve physical and chemical changes which have been referred to in describing the pre-Cambrian rocks, but which cannot be further considered here. They have been most fully discussed in the works of Van Hise.[2]

Vertical Movements.

Movements of the earth's crust which were expressed in variations of the land surface with reference to sea-level were an important condition of the sedimentary phenomena which have been discussed in the previous chapter. As determining results of erosion and sedimentation, uplift and subsidence have repeatedly been referred to. The geographic distribution of these movements and their sequence during the Paleozoic may now be stated apart from the facts from which they are inferred.

[1] This is the maximum value, and the corresponding depth, 610 miles, is the depth at which a given mass would have the greatest weight.

[2] Op. cit., and Metamorphism and Rock Flowage, Geol. Soc. Am. Bull., Vol. IX, pp. 269-328.

UPLIFT.

Uplift with reference to sea-level affected Appalachia and the bottom of the mediterranean sea repeatedly. That is to say, from time to time the land rose higher above sea-level and the sea-bottom was lifted. These effects on land and beneath the sea were not necessarily contemporaneous nor even related; they may either have occurred independently or both together. Uplift, in opposition to subsidence, tended to determine the position and extent of dry lands. Appalachia, the Paleozoic continent, existed, therefore, and prevailed over transgressions of the sea where upward movements with reference to sea-level were greatest. Appalachia constituted an eastern portion of the area under discussion, and it is accordingly inferred that uplift prevailed correspondingly in an eastern district.

SUBSIDENCE.

Subsidence with reference to sea-level was, no less than uplift, a frequent and widespread effect during the Paleozoic. The movements lowered the land-surface and the sea-bottom. Their tendency was to establish and extend marine basins, and, so far as the episodes of sinking were not overcome by opposed uplifts, they did determine the area of the mediterranean sea. As this sea occupied the western portion of the province, it follows reasonably that downward movement prevailed in a western district.

VERTICAL MOVEMENTS IN THE SHORE ZONE.

Between the eastern district, where uplifts prevailed greatly over subsidences, and the western district, where subsidences greatly exceeded uplifts, there stretched a zone in which the opposed movements were more nearly balanced. This was the zone across which the shore frequently migrated. Its width, except during the greatest transgressions or retreats of the sea, was probably less than a hundred miles. The shore zone itself gradually moved westward, however, from its extreme eastern position of Silurian time to the Mississippi embayment of the Carboniferous period. Thus the area of prevailing uplift gradually expanded at the expense of the area of subsi-

dence. The shore zone from the beginning of the upper Silurian to the close of the Devonian extended from New York to Alabama along the present site of the great Appalachian Valley.

During any episode the shore zone was divided into two strips by the line of the shore itself. To the southeast was the coastal plain, wider or narrower as the case may have been; to the northwest was the belt along which sediment gathered to greater thickness than further off-shore. During certain episodes the variation of thickness was gradual and the belt of maximum deposition was broad and indefinite; during others it was narrow and sharply defined by decided differences in thickness of a lens of sediment.

TROUGHS OR DOWNFOLDS.

In the belt of maximum deposition, approximately parallel to the shore, there developed troughs or areas that sank deeper than the adjacent parts of the shore zone. The deepest was that in which the Devonian sediments gathered to a thickness of more than 10,000 feet (Plate VII). These troughs were of the nature of downfolds or synclines. They will hereafter be referred to as original downfolds. They resulted from a local combination of three activities, namely, vertical subsidence, concentrated deposition, and horizontal compression. What share each activity had in producing any particular original downfold may not easily be determined, and the local effect of compression may better be stated in a subsequent paragraph, but the concentration of deposition upon an area of locally greater subsidence may be explained here.

Subsidence was a movement which is recognized as a necessary antecedent condition of the process of sedimentation. Its cause is not known. Local inequalities of subsidence are assumed to have developed. The immediate effect of greater subsidence was to deepen the water over the corresponding area, and currents passing across it were accordingly checked. Flowing less rapidly than before, they were obliged to drop a larger proportion of the sediment they had transported. Thus a locus of greater subsidence became a locus of greater deposition.

The writer does not hold the view that an accumulation of sediment occasions subsidence where that movement has not been initiated by other causes; but it does seem probable that rapid sedimentation may influence the rate of sinking when that movement is already established. Thus where inequalities of subsidence existed the effect of copious deposition may probably have been to increase them.

INITIAL WARPING OF STRATA.

Any thin stratum, when first deposited, may be described as a sheet of sediment, spread on the sea-bottom in an approximately plane attitude. In the case of the Paleozoic strata of the interior sea, the lowest plane was that which was developed by the Cambrian marine transgression, and during the accumulation of sediments, the upper surface at any time usually presented a flat expanse over large areas. These plane surfaces were successively buried as they subsided and later deposits gathered over them, and any one plane was buried under accumulations greater in certain districts than in others. This is illustrated by the contour lines in Plate VII, which delineate approximately the form of the Devonian deposits that buried the black shale. That mass which has been compared to the internal cast of one valve of a mussel shell, was more than 10,000 feet thick in eastern Pennsylvania, and less than 1,000 feet thick in western Ohio. The stratum of black shale conformed to the curved bottom of the mass and was, therefore, warped in general from its original plane attitude.

In the development of original downfolds, described in preceding paragraphs, the strata underlying the area of the downfold were depressed by the local subsidence, and where any such trough developed adjacent to an earlier one the still older strata received a gently undulating form.

It follows from these considerations that the older strata of the Paleozoic system were not parallel to the younger strata, and that the older ones began at a comparatively early epoch to adopt a warped attitude. The warping was increased by each irregularity of subsidence, and the deeply buried strata became accordingly less favorably

situated to resist any force of compression which might affect them horizontally.

Horizontal Movement.

ILLUSTRATIONS.

Some of the more obvious effects of deformation by horizontal movement are illustrated in Plates III, IV, VIII and IX accompanying this article. They are from photographs taken in western Maryland and are striking illustrations of the folds, large and small, which have been produced by compression of the strata in a horizontal direction.

The principal feature of Plates III and IV is an unsymmetrical arch, technically called an anticline, which is cut by the North Branch of the Potomac just above its junction with the South Branch. The titles accompanying the plates fully describe the details which they exhibit. The strata which are seen in the view belong to the Oriskany sandstone at the base of the Devonian. As may be seen, they dip steeply to the southeast (at the left of the picture) and disappear beneath the present surface. Thirteen miles away to the southeast similar strata rise to the surface and are identifiable by fossils as the Oriskany sandstone. Between these occurrences of the Oriskany, in the summit of Sideling Hill, is a strip of the Pocono sandstone, which lies 7,000 feet or more above the Oriskany. From these facts and many others relating to the distribution of the associated strata, it is known that Sideling Hill is situated in the middle of a deep trough, or syncline. The Oriskany strata bend according to the cross-section of the trough and pass under Sideling Hill at a depth of about a mile and a half. On the right of the picture, Plate III, the strata are seen to dip gently under the surface. They there conform to a narrow and shallow syncline, and presently at Patterson Creek reappear in an arch similar to that here illustrated.

The Oriskany sandstone was deposited practically in a flat position as a sheet of beach sand in the manner already described (page 58). It has since assumed the attitude of these folds, large and small; that is, it has been compressed in a horizontal direction. All other

Paleozoic strata of the Appalachian province exhibit similar effects of deformation. The facts were first accurately observed and described by H. D. and W. B. Rogers,[1] and later[2] students have fully confirmed the observations of those great geologists.

GENETIC CONDITIONS OF FOLDING.

In accordance with theories of their day, however, the Rogerses believed that the great mass of the earth was molten beneath a thin, hard crust, which might be thrown into waves or mountain folds by violent agitation of the fluid interior. Although the scientists hold various theories of the condition of the earth's interior, some believing that it may be molten and others that it is a rigid or viscous solid, none now believe the extreme hypothesis entertained by the Rogerses. It is thought that Appalachian folding developed not by a stupendous catastrophe, but by slow and periodic growth, which followed from and was materially influenced by the conditions of previous and concurrent sedimentation. Some of the essential conditions and governing principles of that folding may be briefly stated, so far as they are now understood.

Three sets of conditions existed when folding began in the Appalachian zone, and they may be taken to be the genetic conditions without which the movements would not have occurred when, where, and as they did: (1) there existed a compressive stress or stresses throughout an area of the earth's crust; (2) there was a great thickness of strata of broad extent; (3) in a narrow zone the strata were warped, forming shallow troughs, parallel to which the general trend of the shore was established.

The compressive stresses produced results which sufficiently demonstrate the effectiveness of the forces to move and deform great masses of strata, but the effects do not appear beyond question to show when and in what manner the pressure produced motion, nor how long it continued. Theoretically there are three conceivable

[1] Reports of the Ass. of Am. Geol. and Nat., 1840, 41, 42, p. 508.

[2] On the Physical Structure of the Appalachian Chain, H. D., and W. B. Rogers.

VIEW OF ANTICLINE IN UPPER SILURIAN STRATA IN THE CEMENT QUARRY, CUMBERLAND.

VIEW OF SYNCLINE IN MASSIVE DEVONIAN SANDSTONE, SOUTHWEST OF LITTLE ORLEANS

modes of action which might result in the observed folds and the associated phenomena: (*a*) the effective stress may have originated in the district of uplift, Appalachia, and may have been propagated in a northwesterly direction to the zone where mechanical conditions of the crust made folding possible; or (*b*) the source of activity may have been situated in the area of subsidence beneath the mediterranean sea, and in that case the movement was directed southeastward; or (*c*) the stresses may have developed throughout a wide region and have been directed from the periphery in all horizontal directions inward. Opposed stresses may have balanced, and thus may have tended to raise a dome-shaped uplift or to depress a bowl-shaped one. Then the resulting forms would be conditioned by the resistances of the strata. If those resistances were less in one direction than in any other, greater folds would develop at right angles to that direction, and lesser ones parallel to it. If the least resistance had been nearly equal to the greater resistances, two sets of nearly equal folds should have developed; but if the least resistance had been very much less than resistance in any other direction, one system of folds should greatly predominate. In the Appalachian zone the northeast-southwest system is developed in Paleozoic strata almost to the exclusion of any minor system at right angles to it. Hence if the stresses were toward a common center we should conclude that the resistance from northwest to southeast was very much less than in any other direction. This conclusion accords with deductions from the initial attitudes of the strata due to vertical warping.

The fact that the source of compression is indeterminate is here dwelt on because of the widely accepted inference that the motion was propagated from the southeast. It is not possible here to discuss the mechanics of the problem, but the structures appear to be consistent with either of the several interpretations offered.

Stratification, the second genetic condition of folding, is an essential characteristic of a rock-mass that may fold, and the accumulation of a mass of strata like the Paleozoic system introduces into the earth's crust a weak element of structure. The former proposition

follows from the case with which a number of thin sheets of any material may be bent as compared with the difficulty of bending a continuous mass of equal total thickness. Each thin sheet offers relatively slight resistance to curvature, and the planes which divide the sheets afford opportunity for slipping, which is a means of accommodation. The second proposition follows from the first, if it may be assumed that the floor of the Cambrian sea, which subsided beneath the Paleozoic sediments, was of massive rock. For in subsiding the massive rocks added nothing to the strength of the crust, whereas the strata which replaced them were decidedly weaker when subjected to horizontal compression.

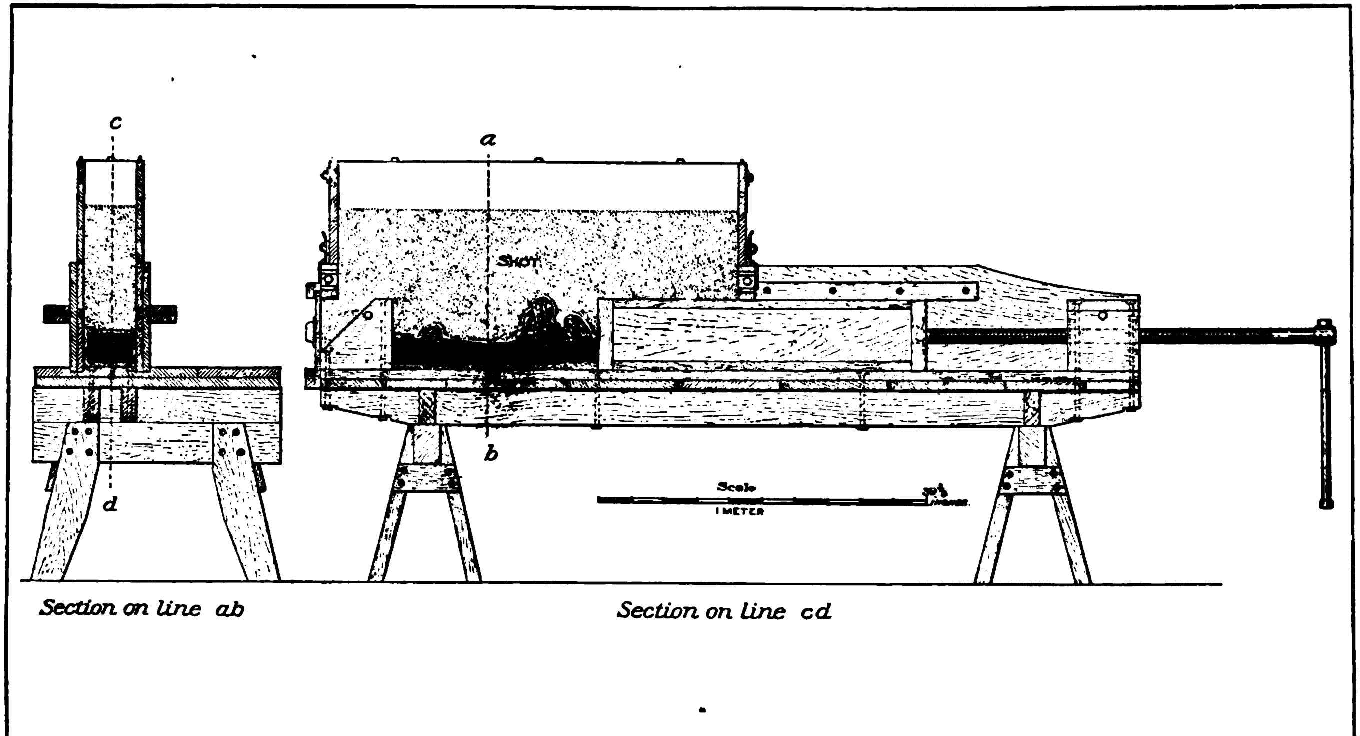
Warping by vertical movement, the third genetic condition of folding, has been discussed with reference to its development by local subsidence and concentrated deposition on page 79. In the map, Plate VII, the contours which define the form of the buried black shale in eastern Pennsylvania are drawn according to the hypothesis that the strata beneath the later Devonian sediments were depressed in gentle flexures corresponding to the deep synclines of the Anthracite regions. This hypothesis rests upon the fact that Devonian strata are somewhat thicker in those basins than on the intervening anticlines, and is part of the broader hypothesis,[1] which will be stated later, that folding was in progress during Devonian time.

Upon strata already warped from a plane attitude the effect of horizontal compression is to exaggerate the established flexures, as if one leans on a bent cane the stick tends to yield at the bend. The influence of very slight deflections from a plane have been demonstrated by experiments of which an illustration is given in Plate X.

The weakness of a warped stratum as opposed to thrust is in accordance with simple mechanical principles, from which it also follows that the resistance which any stratum may offer to horizontal compression lessens as the stratum is warped further from a plane. Thus it might be conceived that a definite compressive stress existed

[1] Mechanics of Appalachian Structure, 13th Ann. Rept. U. S. G. S., pp. 211-281, Plates LXXV-XCVI.

EXPERIMENTAL DEMONSTRATION OF THE DEVELOPMENT OF ANTICLINES ALONG THE LINE WHERE A STRATUM DEPARTS FROM A FLAT ATTITUDE.



DRAWING OF THE APPARATUS EMPLOYED TO COMPRESS MODELS COMPOSED OF LAYERS OF WAX WHILE UNDER A LOAD OF 1000 LBS. OF SHOT.

in flat strata and was ineffective to produce folding, but that the same stress became effective when the strata had been warped by unequal subsidence and deposition. Earlier reference was made to the effect of horizontal compression in producing original downfolds. In the development of downward or upward folds any force transmitted by the strata is resolved into two components at any point of curvature. The one component is tangential to the curve of the stratum, the other is radial to it. The radial component tends to increase the curvature. Thus in the development of original downfolds, from that moment when the deflection of the strata made effective an existing horizontal stress, the initial depression due to vertical movement may have been increased by a component of horizontal pressure.

DATES OF APPALACHIAN FOLDING.

The geologic dates at which folding occurred in the Appalachian province are not yet known; indeed, it has not been determined definitely whether folding was a feature of one episode only, or of several episodes, separated perhaps by long intervals. For half a century it was stated without contradiction that the making of the Appalachian Mountains went forward after the close of the Carboniferous period,[1] and the catastrophe is frequently referred to as the "Appalachian Revolution." This view rests upon positive and negative evidence. The argument might be thus summed up. Carboniferous strata are folded, and therefore folding occurred during or after the close of the Carboniferous period. And all strata from Cambrian to Carboniferous inclusive exhibit an apparent parallelism of bedding. They are what is technically called conformable, in so much of their relations as are preserved and visible to us. This is negative evidence against that unconformity which has been thought to be a necessary result of folding, and it is this negative part of the conclusion which may be questioned.

In Plate XII are shown three stages of development of relations between strata. Figure *a* exhibits the result of a first episode of

[1] Manual of Geology, J. D. Dana, 4th edition, 1895, p. 357.

folding as an anticline might appear if it were not eroded during its growth. Figure *b* shows the effects of erosion, by which the crest of the anticline has been planed down, and of sedimentation by which the eroded detritus is spread in younger strata upon those which were older than the episode of folding. The younger strata are conformable to the older in that section where the latter had not been disturbed, but the youngest are represented as overlapping on and unconformable to the oldest in the anticline. Figure *c* exhibits the effects of a second episode of folding, by which the two earlier series of strata are bent conformably, and suggests the possible relations of strata formed by erosion of the second uplift. The figures are based on a model which was developed experimentally in the press figured on Plate XI, and which is discussed in Mechanics of Appalachian Structure.[1] Reference to the sections published by H. D. Rogers,[2] or from recent surveys,[3] will serve to suggest that erosion may have worn so deeply as to have removed from anticlinal areas evidences of unconformity which might serve to define distinct episodes of development. The negative of this suggestion cannot be considered demonstrated until careful investigation shall have failed to discover evidence of unconformity or of effects of sedimentation attributable to the rise of anticlinal shallows or lands. That investigation has not yet been made and to the hypothesis of a great single revolution by folding in post-Carboniferous time an alternative may be stated with a claim to proof or disproof.

Assuming that a comprehensive stress existed in the Appalachian area, during any epoch of Paleozoic time, it became effective to cause horizontal movement with folding either through its own increase, or through decrease in the resistance offered by the strata, or through changes of both values. Of the strata which were folded, the great Cambrian-Silurian limestone was much the most resistant. It was so thick and yet so massive that it dominated and controlled the development of folds to a remarkable degree, and conditioned the growth of the long parallel structures which characterize the Appa-

[1] Op. cit., Plate XCII. [2] Geology of Penn.
[3] Geol. Atlas of the U. S., Folio 32, Franklin, Va., N. H. Darton.

FIG. 1.—Folds developed experimentally in layers composed of mixtures of wax with other substances. See Plates X and XI.

FIG. 2.—Theoretical section, showing the result of erosion and sedimentation during and after the development of such a fold as that shown in Fig 1. The later strata are comformable to the older in the syncline, and unconformable across the anticline.

FIG. 3.—Theoretic section exhibiting the results of further compression and erosion of the strata shown in Fig. 2. There is no evidence of unconformity remaining.

THEORETICAL SECTIONS BASED ON EXPERIMENTAL RESULTS OF FOLDING.

lachians. The resistance of this controlling stratum was first effected by the sinking of the original downfolds, such as Bays and Massanutten mountains, which contain the great thicknesses of Martinsburg shale, and the correlated synclines elsewhere. The second epoch of development of very deep original troughs occurred during the later Devonian, succeeding the deposition of the black shale. The resistance offered by the great limestone when first consolidated in a flat attitude was probably many times greater than that which it possessed after it had been buried unequally under Silurian and Devonian deposits and had been correspondingly warped. In illustration it may be stated that in compressing a flat model in the apparatus (Plate XI) the combined efforts of two men were required to turn the screw, which, after the folds had developed, could be moved easily with one hand. Hence in the presence of the lessening resistance of the great controlling limestone, a constant horizontal stress, or a growing one, may have become effective toward the close of that deposition which accompanied the warping.

These considerations lead to the suggestion that slight folding may have resulted during the later part of the Lower Silurian and again during the Devonian, and possibly at other dates. It does not follow that the anticlines which developed rose as islands or peninsulas above the sea. Their relation to sea-level was determined by the rate of subsidence of the general area and by their own rate of development in opposition. Furthermore, the surface expression of flexure was probably broad and gentle. If, however, arches did rise above the sea, their growth was probably very low during these initial movements and erosion planed them to sea-level, while sedimentation filled the ever-deepening but shallow intervening synclines. Thus the activity may have been entirely consistent with the facts of the sedimentary record discussed in the preceding pages.

During the later episodes of the Carboniferous, from the close of the Pottsville epoch on, vertical movements were very slight throughout large areas and the surface effects of folding, if folding then occurred, probably found expression in low but rising anticlinal peninsulas and islands, and in shallow but subsiding syn-

clinal bays, lagoons and marshes. The latter were favorable to the accumulation of coal, and upon that assumption their rate of depression may be estimated. Such development implies that strata, but slightly older than those in process of accumulation, were eroded and redeposited.

Toward the close of the Carboniferous period, the deeply buried controlling strata, being gently bent, should have yielded far more readily than when flatter, and thus the accelerated movement resulted in that development of folds which has been called the "Appalachian Revolution." That revolution stands out as an isolated and unaccountable fact, if it be considered as the effect of peculiarly energetic forces which had no antecedents; but it becomes intelligible when it is regarded as a culmination of a stress which became specially effective as conditions became specially favorable.

POST-PALEOZOIC HISTORY OF MARYLAND AND ADJACENT STATES.

The Mesozoic Era.

AN HIATUS.

In a geologic classification of time, the Paleozoic era is succeeded by the Mesozoic era, the era of life intermediate between the ancient and the recent. Although not so long as the Paleozoic, the Mesozoic was an important division of the earth's later history. In Europe and some other parts of the world it is represented by extensive deposits of sediment, but in the Appalachian province that record is meagre and interrupted.

After the Carboniferous land had spread far westward, rising from the shallow waters of the interior sea, the only record made within the province was that which existed in transient forms of hills and plains. They are gone, and there is an hiatus corresponding to an indeterminate lapse of the time which covered the closing episodes of Carboniferous history and the early events of the Jura-trias, the first period of the Mesozoic era.

JURA-TRIAS SEDIMENTS.

Along the Atlantic coast from North Carolina to Connecticut occur several isolated remnants of a voluminous formation, which consists of conglomerate, sandstone and shale, prevailingly of a deep red color. The strata, which are known as the Newark formation, are shallow water deposits, formed probably in tide-swept estuaries.

The areas of the Newark formation occur west of the present Atlantic coast, forming an interrupted belt parallel to the eastern side of the continent. The formation thus appears to be related to estuaries of the Atlantic basin as a scene of deposition and not to the interior sea, in which the known Paleozoic sediments accumulated. In the closing episodes of the Carboniferous and the opening ones of the Jura-trias, there was involved a material change of continental outline. Rising from the western sea, Appalachia had gained in extent in that direction. Sinking beneath the eastern sea, Appalachia lost areas which had not been under water since Silurian time. There is no evidence that the western emergence was related in date or cause to the eastern submergence; indeed, it is probable that the latter succeeded the former only after a prolonged interval, of which the record is wanting.

The Paleozoic extent of Appalachia eastward into the Atlantic is a mooted question among geologists. The argument takes note chiefly of two sets of facts, the volume of Paleozoic sediments and the depth of the Atlantic basin. The mass of sediments deposited in the interior sea was eroded from Appalachia and corresponds in volume to the extent of the continent multiplied by the relative elevation above sea-level which it experienced during the Paleozoic era. Theoretically, the factors, extent and elevation, may be reciprocally varied at will and the total product or volume may remain unchanged. That is to say, Appalachia may be assumed as an extensive or limited land, provided it may be assumed also that elevation was correspondingly moderate or great. In the opinion of the writer, the sediments themselves define the aspect of the land from which they were derived, and, in general, they indicate but moderate relief. Their direct testimony, however, is more definite. The

Silurian (Martinsburg) shale, the Mauch Chunk shales, and the later Devonian formations, are peculiarly thick at certain points. These masses of sediment are analogous in character and occurrence to deposits at the mouths of large rivers, which drained correspondingly extensive lands. They thus seem to represent features of a broad watershed, which extended several hundred miles eastward from the rivers' mouths and beyond the present continental margin.

Against such a former expanse of Appalachia eastward, it is argued that the depth of the Atlantic basin is evidence of the antiquity of the relations of oceanic deep and continental platform, and it is held that their bounds have not materially changed in later geologic time. Where there is so little evidence a conclusion cannot safely be stated; but in the judgment of the writer, the conception of antiquity of an oceanic basin does not involve fixity of its bounds. It is quite possible, as it is indeed probable, that the Atlantic is one of the primeval features of the earth's surface, and yet it may have encroached upon North America by the profound submergence of a zone of the continental platform several hundred miles in width.

An encroachment of the Atlantic basin upon the continental plateau of North America appears to have occurred thus early in the Mesozoic era.

The red sandstones and shales of the Newark formation consisted of detritus of the crystalline pre-Cambrian rocks of Appalachia, eroded and transported eastward to the invading Atlantic. They therefore represent an uplift, which was the last in that complex series of vertical movements of Appalachia which began in the Silurian and continued from time to time prevailingly in the northeastern district of the province during the Devonian and Carboniferous periods. An earlier series of uplifts, the pre-Cambrian and Cambrian movements, had closed with the long interval of almost constant attitude of sea-level which preceded the transgression of the Silurian era upon Appalachia. This later series, closing with the Newark episode, was followed by a second interval of constant relative level of land and sea. It endured throughout the Cretaceous

period and resulted in complete erosion of all previous mountain forms, except in North Carolina and New England.

THE CRETACEOUS PLAIN.

Along the Coastal Plain of New Jersey, Maryland, and other Atlantic States, there is to be seen the edge of sediments of Mesozoic age resting upon pre-Cambrian crystalline rocks. Some of the strata belong to an episode of the Jura-trias period later than the Newark epoch, but the greater part are of the next succeeding period, the Cretaceous. It is the surface of the crystalline rock beneath these sediments which is next to be considered. That surface is a plain, sloping beneath the sediments toward the Atlantic, rising from under the sediments westward toward the Appalachian Mountains. In many localities one may drive up the gentle ascent upon the surface of the plain, and in so driving one rises higher and higher above the streams whose valleys are adjacent. Looking north or south across a valley, the height beyond it is seen to present a long gentle slope like that ascended. Imagining the valley filled with the material which the stream has carried off, one discovers the formerly continuous plain. By extending the process of filling to other valleys in such manner as to connect all ridges whose crests fall into the general slope, there is restored the plain, which was eroded nearly to sea-level during the Cretaceous period.

That old plain, now elevated and dissected, has been traced over New England, over the Middle States, and over the south Atlantic States. It coincides with the summits of the highest ridges, which in Maryland are represented by the Catoctin, the Blue Ridge, the Alleghany ridges, and the Cumberland plateau. Only in North Carolina and the interior of New England are surviving mountain summits of that date, which now rise above their near fellows, as they maintained themselves as hills above the lowland plain in Cretaceous time.

THE CENOZOIC ERA.

THE NATURE OF THE RECORD.

The Cenozoic era is the last. It completes the trio of life eras of which the Paleozoic and Mesozoic are the two earlier. As com-

pared with them, it comprises a relatively short lapse of geologic time, but it is characterized by the development of mammals down to and including the evolution of man.

During the Cenozoic era the Appalachian province has been elevated above sea-level. Such record as the sea has made of physical changes is spread about the margins of the province along the Coastal Plain and in the Mississippi Valley. It is a scant record and one which is not extensively accessible to examination. But it is supplemented by features of the land, whose eloquent statement of their experiences was never appreciated until within the last score of years.

Recognition of the old Cretaceous plain, surviving in the ridge-summits of the present time, is the first step in reading the Cenozoic history of Appalachia. Developed near sea-level, that plain is now 4,000 feet above sea in certain districts and it slopes thence to the coast and to the Mississippi. Thus the dome-like uplift of the Appalachian Mountains and the post-Cretaceous date of the movement may be realized.

A further step toward understanding the expressive landscape is in an appreciation of the efficiency of streams to cut canyons, which are widened to valleys by rains and rivulets. In this process weak rocks yield more readily than resistant ones and valleys develop, therefore, on masses of shale and limestone, whereas heights are long maintained by sandstone beds and other hard masses. Thus streams and divides become generally adjusted to the arrangement of weaker and harder rock masses.

The efficiency of streams to cut canyons depends upon the fall of the stream, among other things, and the down-cutting by streams ceases when they no longer flow so swiftly as to carry away the sediment received from their headwaters and tributaries. Then valleys widen and bottom-lands are built up. As the valleys encroach upon intervening ridges and the latter lessen in volume and height, the aspect of the region tends toward a hilly lowland and ultimately toward a plain. The topography passes from youth through maturity to old age.

At any stage of this process, the region may experience renewed uplift, by which the streams gain fall and deepen their channels. A young canyon is thus developed within the older valley, and the two stages of topographic evolution are distinguishable. In such features as these, and in the many complex relations of streams, plains, slopes and ridges, the later history of Appalachia is recorded. It is a record of intermittent uplift by which the present mountain region has grown as a whole.[1]

The detail of mountain and valley sculptured on the upraised mass is determined by the arrangement of the strata laid down in the vanished Paleozoic sea. The geography, the atmosphere, and the life of that distant time determined initially the plan of the present landscape. They conditioned human existence. Broad farm-lands or craggy crests, fertility or sterility, mineral leanness or wealth, the courses of highways and the sites of cities, all the conditions of man's physical environment, are related in the Appalachians to the long Past, even to the remote Past of the era of ancient life.

[1] Discussions of the development of the Appalachian mountains may be found in the following publications:

Maryland Weather Service, Vol. I, 1899, pp. 41-216.

Rivers and Valleys of Pennsylvania, Wm. M. Davis, Nat. Geog. Mag., Vol. I, pp. 183-253, 1889.

Rivers of Northern New Jersey, with notes on the general classification of rivers, Wm. M. Davis, Nat. Geog. Mag., Vol. II, pp. 81-110, 1890.

Geomorphology of the Southern Appalachians, C. W. Hayes & M. R. Campbell, Nat. Geog. Mag., Vol. VI, pp. 63-126, 1894.

The Physical Geography of Southern New England, Wm. M. Davis, Physiography of the U. S., pp. 269-304. Am. Book Co.

The Southern Appalachians, C. W. Hayes, Physiography of the U. S., pp. 305-336. Am. Book Co.

The Northern Appalachians, Bailey Willis, Physiography of the U. S., pp. 169-202. Am. Book Co.

Physiography of the Chattanooga District, C. W. Hayes, U. S. Geol. Survey, 19th Ann. Rept., Pt. II.

PART II

SECOND REPORT ON THE HIGHWAYS OF MARYLAND

BY

HARRY FIELDING REID AND A. N. JOHNSON

SECOND REPORT ON THE HIGHWAYS OF MARYLAND

BY

HARRY FIELDING REID AND A. N. JOHNSON

INTRODUCTION.

With the exceptions hereafter noted the road-systems and the general condition of the roads throughout the State remain much the same as in 1899, the date of the publication of the "Report on the Highways of Maryland" by the State Geological Survey. The same methods in general prevail. A large portion of the money levied for road-work is distributed at so much per mile irrespective of the urgent need of certain roads or parts of roads. Supervisors feel called upon to leave a trace of their work at every point along the roads allotted to them, with the old result of no practical improvement, each season removing all traces of the previous season's work. In this connection the conclusion drawn in the first report can well be repeated. It was there stated that "the present method leaves very much to be desired, as the thin veneering of improvement upon the roads is soon lost and the roads return to their former condition. With the application of the money for specific improvements the result is far different, since in a few years there is a marked advance in the average condition of the highway. The few cases in which this method has been employed emphasize most strongly the general lack of benefit received from the larger portion of the money spent annually on the roads."[1] While the greater part of the road-work throughout the State is still done under the old and disadvantageous methods, there are instances in several counties, which will be de-

[1] Highways of Maryland, p. 190.

scribed further on, where the money at the disposal of supervisors has been concentrated on the permanent improvement of the worst portions of the roads with much better results. It is not necessary that the amount of money be large in order that it may be economically expended, for the same principle underlies the expenditure of $50 or $5,000, namely, to do only so much as can be done well. The generally bad condition of the roads will never be materially improved until this simple economic principle is followed.

In Baltimore, Prince George's, Harford, Howard, and Anne Arundel counties particularly gratifying progress has been made by the adoption of economic methods in the repair and improvement of some roads.

Operations during 1900 and 1901.

During the last two years the Highway Division has been occupied in giving advice and directions for the improvement of certain roads, and in making tests of macadam materials, of paving-brick and of cements.

The opportunities offered by the Highway Division were brought before the people by several means. The "Report on the Highways of Maryland" was distributed very largely throughout the State. Copies were sent to all County Commissioners, State officials, prominent farmers and other citizens who might be interested in the improvement of the roads. Illustrated lectures on the Roads of Maryland and Modern Methods of Road-Making were given at Hyattsville, Aberdeen, Darlington, Cumberland, Pocomoke City, Princess Anne, Baltimore (three times), and Govanstown. A number of these lectures were in connection with the Farmers' Institutes. Visits were also made to the various Boards of County Commissioners and Road Commissioners in the State, and the aid of the Highway Division freely offered.

Correspondence of the Highway Division.

The following circular and enclosures, which were sent to all Boards of County Commissioners in the spring of 1900, describe the

methods of procedure which it was thought advisable to adopt in aiding in the improvement of the roads:

MARYLAND GEOLOGICAL SURVEY, JOHNS HOPKINS UNIVERSITY.

BALTIMORE, March 30, 1900.

Chapter 454, Laws of Maryland, 1898, gives to the Maryland Geological Survey, among other powers, that of making plans of roads. As it would be of little value to survey roads upon which no improvement is contemplated in the near future, the following plan has been adopted in order to insure the most useful results:

When a county intends making any considerable improvement to a portion of a road, the Highway Division is ready to give such information as may be desired by the Board of County Commissioners, both concerning the approximate cost and the best methods of construction. In this way estimates of the cost of properly grading, draining, and surfacing a particular piece of road can be had, which will be of value to the county.

To avoid confusion, and also make clearer the method of procedure, blank forms are inclosed, which are to be filled in as indicated.

The *first form* is for a request for a *preliminary examination.* This consists of a superficial examination of the road with some study of the available road materials. When this is done a rough estimate of the cost of the proposed improvement to the road can be made. If the County Commissioners decide that the improvement shall be undertaken, they can fill up the *second form*, which is a request for a *detailed survey and estimate of cost.* This includes making a plan and profile of the road, showing proposed changes in the location and in the grades, and tests of the material submitted for use. Further, if work is carried on under plans and specifications furnished by the Highway Division, a general supervision of the construction could be undertaken by the Division, should it be so desired.

At the laboratory of the Survey there are facilities for making tests upon different materials for surfacing aud paving roads and streets. Much information is already at hand concerning the qualities of the different rocks in various localities, which will be found in the recent report on the Highways of Maryland, together with a description of the tests on macadam materials. Since the publication of this report a machine for testing paving bricks has been added to the equipment, so that tests can be made of the various samples of brick submitted to cities or towns of the State for street pavements. On application, blanks will be furnished with printed directions for sending samples to be tested.

It is the aim of the Highway Division to encourage the adoption of such methods as will result in the most economical form of road construction, and thus gradually to better the condition of the highways of the State.

The Highway Division is supported by the State, and no charge is made for its services. The money at hand for making surveys and estimates is limited, and there may be a greater demand for such work than can be met; every effort will be made, however, to comply with all reasonable requests, either from County Commissioners or from other persons wishing to improve the public roads.

MARYLAND GEOLOGICAL SURVEY, HIGHWAY DIVISION.

Request for Preliminary Examination of..........................road in
....................................county.

The County Commissioners of ....county contemplate improving a portion of the road known as................................
beginning at a point ....
and extending ....miles toward................................

Before beginning this work the Board of County Commissioners consider it desirable to have an approximate estimate of the cost of improving the section of road above mentioned and for that purpose request that a preliminary examination be made by the Highway Division of the Maryland Geological Survey.

Signed,

Date,............... ....

Clerk to Board of County Commissioners.

MARYLAND GEOLOGICAL SURVEY, HIGHWAY DIVISION.

Request for a Detailed Survey of.................................road in
....................................county.

The Board of County Commissioners of..........................county consider that action should be taken towards the improvement of a portion of the public highway known as..
road and have decided to improve the portion of this public highway beginning at a point near..
and extending.........miles more or less towards.........................
as far as may be practicable.

The Board requests the Highway Division of the State Geological Survey to make such surveys and plans as may be necessary to obtain a detailed estimate of the cost of this improvement and to draw up suitable specifications for the work.

Signed,

Date,............... ....

Clerk to Board of County Commissioners.

The following circular was sent to all Farmers' Clubs and Granges, accompanied by the circular and blanks mentioned above:

MARYLAND GEOLOGICAL SURVEY, JOHNS HOPKINS UNIVERSITY.

BALTIMORE, July, 1900.

Secretary of...................................

DEAR SIR:—The inclosed circulars will explain in part the work the Highway Division of the Maryland Geological Survey is anxious to carry on. It is believed that much money is now spent on the roads to little advantage because no definite knowledge of the cost of a contemplated improvement is at hand before the work is begun. Thus it is often the case that an improvement has been begun which the money at hand was insufficient to

finish properly, resulting in a very inefficient use of the funds; whereas, the same sum concentrated on a smaller length of roadway might have made a substantial permanent improvement.

The Highway Division, with the many practical illustrations of this kind in mind, considers that no more useful piece of work can be found than supplying beforehand the data for estimating as closely as possible the cost of proposed road-improvements. No interference with the powers of the road-officials in the different counties is at all contemplated or possible. It is merely desired that they shall know of the opportunity which exists for them to obtain estimates for road-work with little or no expense to the county.

Past experience has shown, in addition to helping the county officials, that much can be done by offering the same aid to the farmers of different neighborhoods who propose to improve the roads in their vicinity at their own expense. The same aid which would be given to the county officials will be given to any organized effort on the part of the people themselves.

Requests for examination of roads can be made on the same blanks as those prepared for the County Commissioners by merely striking out the unnecessary lines. Another way would be for those directly interested in a proposed improvement to petition the County Commissioners or other officials, as the case may be, to request that a report on the cost be made by the Highway Division before beginning the work.

The permanent improvement of the roads of the State can be secured only by the efforts of many influential persons, and it is hoped that your club will do all in its power towards the encouragement of an efficient and economical system of road construction; the first step in this direction is to have at hand a full knowledge of the cost of the different ways in which it may be possible to improve a given piece of road, together with the relative values of the various road-making materials that can be obtained.

It is further asked that your club make known to the County Commissioners that you have received this communication and, should it seem advisable, to request them to give this matter their serious attention. They would do this the more readily if they recognized it was considered a matter of vital interest by such organizations as the Farmers' Clubs.

Very respectfully,

The following letter, together with the circular and the blanks, was sent to the editors of all the papers in the State, many of whom published more or less extensive notices:

MARYLAND GEOLOGICAL SURVEY, JOHNS HOPKINS UNIVERSITY.

BALTIMORE, July, 1900.

***To the Editor of*.................................**

DEAR SIR:—Will you kindly give such notice of the inclosed papers as you may think will be of public interest. It is our object to let the people know of the opportunity there exists for obtaining the aid of the Highway

Division in all matters relating to public roads. A notice in your paper will have the effect of calling general attention to this matter and so bring it in the end more emphatically before the County Commissioners.

Very truly yours,

FIELD WORK.

As a result the Highway Division has been called upon to examine and report upon the following roads:

Anne Arundel county.—Baltimore and Annapolis road, South River road.

Baltimore county.—Green Spring Valley road, Garrison road, Glencoe road, Govanstown sidewalk.

Carroll county.—Eldersburg-Sykesville road.

Frederick county.—Brunswick-Petersville road, Knoxville-Petersville road.

Harford county.—Archer's Hill road, Belair-Churchville road, Main street, Belair.

Howard county.—Old Frederick road from Davis lane to Marriottsville road and at Hollofield station, projected road along Rockburn Branch, Woodbine-Lisbon road.

Prince George's county.—Baltimore-Washington road, T B road, Central avenue, Sheriff road, Oxon Hill road, Riggs road, Suitland road, Queen Anne road.

Talbot county.—Claiborne road.

On all of these roads, with the exception of the Claiborne road, the Eldersburg-Sykesville road, the Knoxville-Petersville road, the Woodbine-Lisbon road and the projected road along Rockburn Branch, and Main street, Belair, surveys were made and plans and estimates submitted. The following roads have been improved according to the plans, and in some cases under the supervision, of the Highway Division: South River road, Green Spring Valley road, Garrison road, Glencoe road, Govanstown sidewalk,[1] Belair-Churchville road, Old Frederick road, Baltimore-Washington road, T B road, Oxon Hill road, Riggs road, Suitland road and Central avenue.

The detailed account of these roads will be given further on.

[1] The work on this sidewalk is to be done in the spring.

SURVEYS.

The surveys of roads made by our engineer and his assistant have been made as cheaply as possible, consistent with the requirements in each case. No attempt has been made to measure closer than one part in 5,000, while in most of the work an accuracy of only one in 2,000 has been allowed. Measurements to tie-stakes and other check-marks have been taken to the nearest tenth of a foot. In running a traverse along a road the angles have always been measured to the right, thus avoiding any possibility of deflecting the course the wrong way when plotting. The angles have been read to the nearest minute simply because the instrument used reads to minutes, not that the work as a rule requires such close reading. The angles have been checked by magnetic bearings taken on each course. Stakes have been left along the side of the road at intervals of one hundred feet to mark the survey stations.

The surveys have been made not to mark the limits of properties, but to furnish the information necessary to make plans for the economical improvement of the road, to determine the grades to be adopted, and to estimate the amount of excavations and the cost of the work. The accuracy adopted was regarded as quite sufficient for these requirements, and the expense of the survey is materially less than is usually the case in such work. Generally the plans have been drawn to a scale of 40 feet to the inch and cross measurements, locating the edge of the roadway, fences, etc., have been taken only closely enough for purposes of plotting on this scale.

Much greater care is necessary in determining the levels as they are used for purposes of grading and for calculating the amount of the excavation. It might appear that if a station could not be re-established closer than one foot, it would hardly be necessary to determine levels very accurately; but it must be remembered that an error in the relocation of a station on a slope as great as 10 per cent could, at most, only result in an error of elevation of one-tenth as much, and it would usually be less. On all the surveys numerous bench-marks were established which can easily be identified and recovered at any future time. Their elevations are recorded to the

hundredth of a foot. All other elevations have been taken to the nearest tenth of a foot. The datum plane assumed in different localities generally has reference to some permanent mark or object in the immediate neighborhood but no particular reference to the sea-level. To refer all elevations to sea-level would in most cases have required considerable additional work which would be of no real advantage to the work in hand. In some instances, however, where connections could readily be made with bench-marks established by the U. S. Geological Survey, the elevations have been referred to sea-level.

The plans are usually drawn to show the location of the edges of the roadway and the location of fences along the road, together with an indication where dividing fences exist. So far as possible the names of the owners of adjacent property along the road have been given, also the location of telephone and telegraph lines, where they exist. The position of each station of the traverse from which fence lines and other features were located is shown together with tie-measurements and angles wherever deflections were made. Fronts of buildings within 100 feet or so of the road have usually been plotted, also bridges and drains.

The profile shows the elevation of the center of the travelled portion of the road, also the elevation of cross-drains, bridges and streams. The new grade, where one is established, is shown, giving the amount of cut and fill as the case may be at each station where a change is to be made. Thus anyone familiar with this class of work can by the aid of the plan and the stakes along the road know exactly how much cutting and filling is to be done at all parts of the road. The exact location, with a description and elevation, of all bench-marks is given on the plan. The aim has been to make the information given on the plan and profile as complete as possible, so that any surveyor could lay out work on the ground by their aid without referring to the field notes.

The preparation of the plans includes plotting on brown paper in pencil. From this brown-paper drawing ink tracings are made on linen, on which also the title is marked. The lettering of the title is

set up in rubber type, which is stamped upon a piece of paper and thus very readily traced, the minimum amount of time being given to this portion of the work consistent with clearness and neatness. All the tracings and also the brown-paper plans are kept in the office. From the tracings blue prints are made and sent out to those who require them, but in no case are the tracings sent out of the office. The omission of unnecessary refinements has kept down the cost of the surveys, including the preparation of the plans and estimates, to between $20 and $35 per mile.

CONTRACTS.

In improvements of importance the Highway Division has always recommended that the work be done by contract, and its advice has been followed in some cases, notably the Belair-Churchville road, the Riggs road, and the Old Frederick road. In the last-mentioned case the grading was let by contract in a somewhat unique manner. The plan and profile had been made, showing the cuts and fills at the different stations, which had been marked on the ground by stakes. The contractors were invited to meet on a certain day on the ground to bid on the work. The plans and profile were explained to them by the Highway Engineer of the Highway Division and all the work gone over in detail. Bids were then asked for the grading in accordance with the plans and profile shown. The bidding was done as at an auction, the competing contractors underbidding each other, and the contract was given to the lowest bidder. The first bid was for $1800, which was finally bid down to $1225, at which price the contract was awarded. The estimate which had been made by the Highway Division was $1218.

THE ROLLER AND THE WIDTH OF ROADS.

The use of a roller in making roads is of the utmost importance. It not only makes a smooth road from the first, but it tends to break up the system of tracking which is fatal to any road which is much used, and it also saves the material of which the surface is made. It is unfortunate that this practice is neglected in the construction of

the many shell roads of the tide-water counties. As a result, a greater quantity of shells is required, the road when first made or when repaired is in very bad condition and frequently the horse- and wheel-tracks are deeply worn before the shells are well consolidated. This is especially true of narrow country roads which are not much travelled, as is forcibly illustrated by a road near Salisbury, shown in Plate XVI, Fig. 2. This road was being shelled in the spring of 1901 to a width of about ten feet. In the immediate neighborhood of the town, where the road is wide and where there is much traffic, the wagons have driven over all parts of the road and worn the shells down to a fairly even surface, but a short distance further out of town, where the road is narrower and much less travelled, tracking had worn great ruts three or four inches deep before consolidation had even begun. The use of a light roller was urged, but the suggestion was not followed. If the road had been made quite smooth by rolling, and tracking prevented by occasionally obstructing a few feet of one side of the road, it could have been kept in much better condition. The view of this road shows the beginning of the freshly covered portion and the ruts are well seen.

The disadvantage of a too narrow road is also illustrated in the case of a short piece of the Belair-Churchville road, improved in 1898 under the direction of the late Mr. E. G. Harrison, Road Expert of the Bureau of Road Inquiry at Washington. A distance of about 600 feet was surfaced with trap rock and well rolled, making an excellent piece of roadway, but the width of the stone surface was in places only about 10 feet. As a result wagons keeping in the middle of the road have followed the same tracks, and at the time of going to press the road is already beginning to wear in ruts.

The tendency to drive in the tracks of former wagons is very great. Two methods have been used to prevent it, and the tendency itself is diminished if the road is perfectly smooth and not too narrow. In Massachusetts signs have been placed along the roads built by the Highway Commission reading: "Don't drive in the middle of the road." In Saxony, long white stones are temporarily placed on one side of the road to force the travel to the opposite side. By changing

these stones from time to time the travel is made to go over all parts of the road. In parts of our own State, especially on the Eastern Shore, wooden logs might be used in the way stones are used in Saxony.

ECONOMY.

Recognizing the importance of economical construction, the Highway Division has aimed to reduce the cost of improvement to the lowest possible figure, and all plans have been made for the simplest construction. As pointed out in our first report, it is unwise to surface a road having heavy grades, for these grades will always be a great disadvantage, and if the road is much used they must at some time be taken out and the surfacing lost. We have therefore invariably advised the lowering of heavy grades, and where the sum available was insufficient to grade and to surface, we have advised the grading first and the postponement of the surfacing, or the postponement of the whole work until a sufficient amount could be applied to do it all properly. The grades that can be allowed depend on the topography of the region. It is best to keep grades down to at least 5 per cent, though in certain cases 7 or even 8 per cent have been allowed.

LABORATORY WORK.

During the past two years there has been a great increase both in the amount and scope of the laboratory work carried on by the Highway Division. The increasing use of brick as a paving material by the cities and towns of Maryland has led to the installation of brick-testing apparatus. The City of Baltimore was about to let contracts for paving-brick in the spring of 1900, and the apparatus was installed after an assurance from the City Engineer's Department that the opportunity to have tests made would be of great benefit to the city. The first test was made in July, 1900, and up to the present time over 140 tests have been made, which required more than 1700 brick of an aggregate weight of 7½ tons. The necessary equipment for these tests consists of a brick-rattler, a machine for making cross-breaking tests, and an impact machine.

The testing of cements to be used in public works has proved of great value in various cities where it is done. In Philadelphia a very elaborate equipment has been installed in the City Engineer's office. Tests of this kind are also made by the State Engineer of New York in Albany, by the Ministry of Public Works in Paris, and in many other places. A machine for testing cements has been set up in the laboratory of the Highway Division and a number of cements have been tested.

Tests of macadam materials have been continued and improvements made in the methods employed.

DISTRIBUTION OF INFORMATION.

To bring the opportunities offered by the Highway Division for testing the qualities of paving-brick to the attention of the officials of the cities and towns of the State, the following circulars and blank forms were sent to the mayors or the engineers of these cities and towns, and personal visits were made to many of them. As a result tests have been made for Baltimore, Annapolis, and Cumberland.

MARYLAND GEOLOGICAL SURVEY, JOHNS HOPKINS UNIVERSITY.

BALTIMORE, MD.

BRICK-TESTING FOR CITIES AND TOWNS OF MARYLAND.

The use of brick as paving-material for cities and towns is rapidly increasing since brick makes one of the cheapest and best street pavements. To insure having a good brick pavement, however, it is essential that the brick should possess durability and strength. The manner in which these qualities can best be determined is by actual wear, but as this necessitates a considerable expense in laying a number of brick in the street and also requires time before any result can be obtained, there have been devised a number of laboratory experiments which are comparatively inexpensive and require but a short time to test thoroughly the character of the brick.

The Highway Division of the Maryland Geological Survey has installed a complete outfit of machinery suitable for making the standard tests recommended by the National Brickmakers' Association. The first of these is an abrasion test by which the brick are submitted to the wear of cast-iron shot in a revolving iron drum. The second test gives the resistance of the brick to cross-breaking. The third test gives the amount of water which the brick absorb in a certain time.

It is suggested that those towns contemplating the laying of brick pavement should request the manufacturers to send samples of their brick to

the State Highway Laboratory to be tested before any brick are purchased. This will enable the town officials to ascertain which of the different bricks submitted give the highest tests, and they can also require that the manufacturers shall furnish brick of a quality equal to that submitted for tests. To do this it will only be necessary to specify that a number of brick will be taken from each shipment and tested, and if found deficient the lot will be rejected. This would insure a careful selection of brick by the manufacturer if he knew that there was a liability of tests being made. If all the officials in the different cities of the State should pursue a plan similar to the one outlined, the different manufacturers of paving-brick would come to recognize that a standard quality of paving-brick was required, with the result that a more careful selection of such brick would be made for shipment to this State.

Tests are made free of charges, except those of shipment, in the Laboratory of the Highway Division of the Maryland Geological Survey at the request of any county or city official of the State. Application blanks will be furnished on which directions for shipment of samples are given. Usually manufacturers are willing to send samples to be tested at the request of any city official. City officials are asked to fill out the enclosed blanks and return them to this office, at the same time directing the manufacturers to send the samples of brick directly to the Laboratory.

Very respectfully,

(Enclosure.)

MARYLAND GEOLOGICAL SURVEY, HIGHWAY DIVISION.

BALTIMORE, MD.

The attention of the county, town, and city officials of the State is called to the opportunity that exists for having paving bricks and all kinds of macadam materials tested free of charge, save that of transportation, at the laboratory of the Highway Division of the Maryland Geological Survey. At the request of any public official of the State the tests will be made from samples sent to the laboratory of the Highway Division, and a report made on the results. It is not essential that the materials be produced within the State.

No report will be made to persons outside the State, but the officials for whom the tests are made are at liberty to make public the results.

DIRECTIONS FOR SENDING SAMPLES.

Samples should be sent to the "Highway Division, Maryland Geological Survey, Johns Hopkins University, Baltimore, Md.," with all charges prepaid.

For a test of macadam materials about fifty pounds are required, preferably in large pieces. For a test of paving brick thirty to forty bricks are needed, the larger number where the bricks are of small size.

(Fill in the following blanks and return to this office.)

APPLICATION FOR TESTS.

. . . . *190* .

Maryland Geological Survey, Division of Highways:

GENTLEMEN—You are requested to make tests on paving materials which have been sent to the laboratory of the Geological Survey, transportation prepaid:

MACADAM MATERIAL.

Location of quarry ....

Owner of quarry ....

[Name and address]

Operator of quarry ....

[Name and address.]

Sample selected by ....

[Town or city officials, contractor or manufacturer.]

PAVING BRICK.

Where clay was obtained ....

Where brick was manufactured ....

Manufacturer ....

[Name and address.]

Sample selected by ....

[Town or city officials, contractor or manufacturer.]

Respectfully yours,

....

....

Photographs of the apparatus used in the laboratory tests of brick and of road-materials, with explanations and with specimens of the materials before and after the tests, were exhibited at the Pan-American Exposition at Buffalo last summer. The only other exhibit of the kind was that of the office of Road Inquiry of the U. S. Department of Agriculture. The exhibit is now displayed at the Charleston Exposition.

BRICK TESTS.

Three tests are made to determine the relative values of various bricks as paving material. The abrasion or rattler test shows how well the brick will resist wear when in use. This is usually considered the most important of all the tests. The cross-breaking test measures the resistance which the brick offers to breaking under heavy loads; and the absorption test shows how much water it will absorb. A brick which absorbs much water will suffer disintegration in frosty weather. An impact test is being developed to determine the toughness of the brick.

Abrasion or Rattler Test.

A number of brick are placed in an iron barrel or rattler with a charge of iron shot and rotated 1800 times, and the amount worn from the brick is determined. The rattler used in this test consists

FIG. 1.—DUVAL MACHINE FOR TESTING THE WEARING OF ROAD-MATERIALS.

The Friedenwald Co.

FIG. 2.—BRICK RATTLER FOR TESTING THE WEARING OF PAVING-BRICK.

TESTING MACHINERY.

of an iron barrel, whose inside length is 20 inches and diameter 28 inches, as recommended for the standard test by the National Brickmakers' Association in 1900. The sides are made of 14 staves separated from each other by spaces $\frac{1}{4}$ inch wide. A machine of this kind was purchased in the market but required some alterations, which were made in the machine-shop of the Highway Division. The cast iron sides with which the machine was originally fitted broke one after another under the repeated blows of the charge inside the cylinder and were replaced by sides of rolled steel. It was also found necessary to add a gear wheel to turn the barrel. Plate XIII, Fig. 2, shows the rattler as now used, fitted with the additional gear and steel sides. To increase the wearing away of the brick as they are revolved in the cylinder, cast iron shot is added to the charge. This shot consists of 10 pieces, each $4\frac{1}{2}$ inches by $2\frac{1}{2}$ inches, weighing 75 pounds; and 225 pounds of $1\frac{1}{2}$ inch iron cubes. The shot is cast with slightly rounded edges and allowed to remain in the cylinder until 10 per cent of its weight has been worn away. In order to make all tests exactly alike, a few of the most worn pieces, generally between 14 and 20, are taken out at the end of each test and replaced by an equal number of fresh shot. This insures having the charge of shot in the same condition for each test, in spite of the rapid wear of the iron. Experiments were made with shot of chilled cast steel and the results were very satisfactory, no perceptible wear of the shot being noticed after 100,000 revolutions. If chilled cast steel were used in brick tests, it might be best to use three or four models with different radii of curvature on the edges, so as to correspond to the cast iron when partially worn. A charge of shot of this kind would give the same results and be practically indestructible.

The number of brick used for a test varies with the size of the brick, being the nearest whole number of brick that will equal in volume 10 per cent of the volume of the cylinder. The volume of the cylinder equals very nearly 12,000 cubic inches, so that the number of brick used for a test varies from nine to fifteen. The weight of a charge of brick is usually between 90 and 100 pounds and the total weight of the charge in the cylinder, including the shot, about 400

pounds. The cylinder is revolved 1800 times at the rate of 30 revolutions per minute. The brick are carefully weighed before and after the test, the loss being expressed in percentage of the weight of the original brick. The material worn from the brick passes out through the spaces between the sides and does not form a cushion to protect the brick from wear. The loss suffered in this test varies between 15 and 30 per cent, or even more, of the weight of the brick. The city of Baltimore requires that the brick to be used on its streets

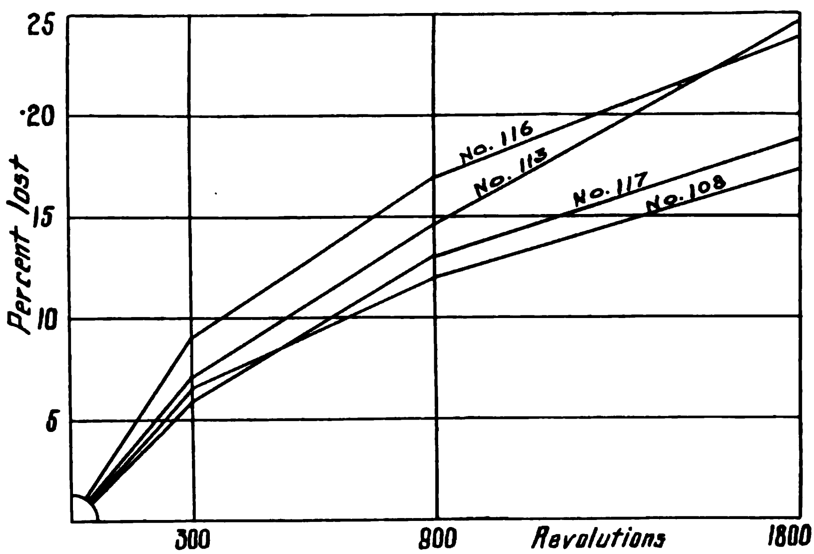


FIG. 2.—Curves showing rate of wear for different paving brick during rattler test.

shall not lose more than 18 per cent of its weight when subjected to the above test. A brick that has lost this much, nearly a fifth of its volume, in the rattler, has worn through the outer surface and, therefore, this test does not discriminate between the wearing power of the original surface and of the body of the brick, though it does give the wearing power of the brick in the long run. Some brick might be too brittle on the surface but very hard inside. Brick of this kind, if laid, would chip and seem to be wearing very badly during perhaps the first year, but would wear more slowly afterwards; whereas, an-

other brick, which would not last so long, might have a surface of better temper and might when first laid appear to be the better brick.

In order to test the varying quality of a brick from the surface inwards, a number of tests were made, stopping the rattler and weighing the brick after 300, 900 and 1800 revolutions. The results are given in the following table and shown graphically for four makes of brick in the curves of Fig. 2. They show the percentage loss in

TABLE SHOWING RESULTS OF SPECIAL RATTLER TESTS OF PAVING BRICK.

No.	Name.	Per cent worn off at end of		
		300 revs.	900 revs.	1800 revs.
108	Iron Rock Block	6.5	11.9	17.2
111	Guise Block	7.2	15.1	23.5
113	Porter Block	7.0	14.5	24.5
114	Maxwell Block	7.1	13.8	21.9
116	Townsend Block	9.0	16.8	23.7
117	Montello Block	5.8	12.9	18.7
120	Mack Block	5.3	11.5	20.6

terms of the number of revolutions. Each number gives the average of two tests. It will be noticed that the curves are steepest in the first part of the test, which is due to the breaking off of corners and edges. But the greatest interest centers in the differences between the various curves. Some, such as 113 and 116, keep a nearly uniform slope after about 300 revolutions, showing that these brick wear as well on the surface as below; whereas others, such as 108 and 117, wear better after their original surface has gone. These differences will undoubtedly show themselves in pavements made of these various bricks. It also appears that the 1800 revolutions of the complete test are sufficient to determine the relative wear of the brick for long periods.

A very interesting experiment has been undertaken by the City Engineer's Department of Baltimore. Holliday street, between Baltimore and Fayette streets, has been paved with a number of different kinds of brick, each kind being used for a short section. Specimens of the bricks have been subjected to the special tests just described. The relative wearing power of the various bricks can be determined

in the future and the results compared with the tests. A complete report of this work will appear in the Report of the City Engineer for 1901.

Cross-breaking Test.

The standard test, as recommended by the National Brickmakers' Association, consists in placing the brick in the same position as when laid in the pavement, on two cylindrical knife edges which are 6 inches apart; bearing on the top of the brick exactly midway between the two lower knife edges is another knife edge with a longitudinal curvature of 12 inches radius and a cross-section curvature of 1 inch radius. Pressure is applied to the upper knife edge until the brick is broken, and the pressure and the dimensions of the brick are measured. The modulus of rupture, in pounds per square inch, is then computed from the formula $R = \frac{3}{2}\frac{W}{A}\frac{L}{D}$, where R is the modulus of rupture, W the breaking load (in pounds), L the length between supports (in inches), A the cross-section of the brick (in square inches), and D the depth of brick (in inches). The formula is applicable only to brick of rectangular cross-section. The machine used for making the cross-breaking tests is shown in Plate XV, Fig. 2, and consists of two I-beams 10 feet long, hinged at one end to strong steel straps, the other ends being hung in stirrups connected with a small Olsen compression machine (not seen in the picture) with a capacity of about 5000 pounds. The upper knife edge, through which the pressure is carried to the brick, is one foot from the fulcrum of the two I-beams, thus making it possible to develop a pressure of 50,000 pounds with a ten-foot beam. It will be noticed that the two lower knife edges, on which the brick rests, are supported on a cylindrical piece of steel, which in turn rests in a V-shaped iron trough. The cylindrical piece of steel is in two parts, so that each knife edge is oscillated separately in a plane parallel to its axis, thus keeping the knife edges at a constant distance apart, and at the same time allowing them to conform to the surface of the brick however much warped. If care is not taken in this particular many of the tests would prove unsatisfactory, owing to the frequent occurrence of irregular breaks beginning at one of the lower knife edges and running in a curved

line to the upper knife edge, instead of a clean break exactly across the middle of the brick. With the device here described little trouble has been experienced from this cause. The apparatus for the cross-breaking tests was designed in the laboratory of the Highway Division. The cost, exclusive of the small Olsen machine which weighs the pressure, was about $100. The Olsen machine cost about $50.

Absorption Test.

This test consists in placing specimens of the brick, which have been through the rattler-test, in water for forty-eight hours and noting the increase of weight due to the water absorbed. The brick are dusted, thoroughly air-dried and carefully weighed before being placed in the water. When taken out at the end of 48 hours the surplus water is removed with a sponge or cloth and the brick again carefully weighed. Five specimens are used for a test and the result is given for the average of the five. The amount of water absorbed is given in per cent of the weight of the dry brick. The object of this test is to guard against the use of brick which absorb water too readily and which would therefore suffer much from frost action. An absorption of over 3½ per cent is regarded as too much.

Impact Test.

Experiments are being carried on to determine the toughness of brick by means of an impact test. Small cylinders, one inch in diameter and one inch high, are cut from the brick by means of a core drill. The cylinders are then subjected to a series of blows of increasing force until broken. The blows are delivered by means of a hammer, weighing one kilogram, raised through heights, increasing successively by one centimeter, and dropped. The height of the blow which breaks the specimen represents the toughness of the brick.[1] The machine by which this test is carried out is the one formerly used for determining the cementing power of rock dust,[2]

[1] This test is similar to that used for testing the toughness of rocks by the Massachusetts Highway Commission, and described in their report for 1897, page 65.

[2] Highways of Maryland, pp. 323, 324.

somewhat altered. The important alterations consist in using a more compact hammer and in replacing the rotating screw, which raised the cross-head, by means of which the hammer was lifted, by a round leather belt carrying a small steel collar which engages the cross-head. The machine thus works much more rapidly when high falls are required. Perhaps the most important improvement is the solid base, entirely disconnected from the rest of the machine, on which the specimen is placed, thus relieving the machine of the serious jar caused when the hammer falls. This base consists of a short iron column with a top of hardened steel, projecting through the base of the machine; below it is cast into a solid iron block, which in turn is bolted upon a brick pier. A picture of the modified machine is given in Plate XIV, Fig. 1. It has not yet been long enough in use to yield valuable results.

The following form has been adopted for reporting the results of the brick tests:

REPORT OF PAVING BRICK TEST.
MADE IN THE
LABORATORY OF THE HIGHWAY DIVISION,
OF THE
MARYLAND GEOLOGICAL SURVEY,
BALTIMORE, MD.

WM. BULLOCK CLARK,
State Geologist.
HARRY FIELDING REID,
Chief of Highway Division.
A. N. JOHNSON,
Highway Engineer.

Test No. .... Date..........................

DETAILS OF TESTS.

RATTLER TEST. This is the standard test recommended by the National Brickmakers' Association, viz: length of rattler, inside, 20 inches; diameter, inside, 28 inches; 14 sides; space between sides ¼ inch wide; number of revolutions, 1,800; speed, 30 per minute; weight of cast-iron shot, 300 lbs.; 225 lbs. of 1½ in. cubes; 75 lbs. of 4½ in. x 2½ in.; amount of brick for a test, 10 per cent of volume of the cylinder, using nearest number of whole brick.

CROSS-BREAKING TEST.—Brick placed on knife edges 6 in. between centers. These knife edges are cylinders with ½ in. radius. Pressure is applied midway between the two lower knife edges by single knife edge having circular cross section of 1 in. radius and longitudinal curvature of 12 in. radius. Brick tested in same position as when placed in pavement. The total cross-breaking strength is the actual number of pounds required to break the brick. The modulus of rupture is computed from the formula, $R = \frac{3WL}{2AD}$ — where R = modulus of rupture, W = breaking load (in pounds), L = length between supports (in inches), A = area of cross-section (in square inches), D = depth of brick (in inches); formula applicable only to rectangular cross-sections.

The Friedenwald Co.

Fig. 1.—OLD PAGE MACHINE REMODELED AT THE LABORATORY OF THE HIGHWAY DIVISION TO MAKE IMPACT TESTS ON STONE AND PAVING-BRICK.

Fig. 2.—PAGE-JOHNSON MACHINE DESIGNED AND MADE AT THE LABORATORY OF THE HIGHWAY DIVISION FOR TESTING THE CEMENTING VALUE OF STONE DUST.

TESTING MACHINERY.

ABSORPTION TEST, made on brick which have passed through the rattler test and are thoroughly air-dried.—Immersed in water for 48 hours, surplus water removed by blotting paper, brick weighed before and after immersion. The amount of water absorbed given in per cent of weight of dry brick.

Brick manufactured by ....
Description ....
Test made at the request of ....
Sample selected by ....
Average size..................
Average weight................

RESULTS.

RATTLER TEST,	- - - - - -	.........per cent lost.
TOTAL CROSS-BREAKING STRENGTH (average of....specimens),		..........lbs.
MODULUS OF RUPTURE (average of....specimens),	- -	..........lbs. per sq. in.
ABSORPTION TEST (average of....specimens),	- -	..........per cent.

Remarks: ....
....
Highway Engineer.

The following table gives the results of tests made upon samples of paving brick, sent to the laboratory by city or other public officials. Nearly all the tests here given were made for the City Engineer's Department of Baltimore. A large number of the samples were selected by the manufacturers, many others were selected from car-load lots by the City Engineer's Department. As much greater weight is given to the rattler test than to the others, this alone was wanted for many of the samples, which accounts for the blanks in some of the columns. Where a large number of tests have been made of the same make of brick the average is given, together with the maximum and minimum results. The results under the columns headed: "total cross-breaking strength," "modulus of rupture," and "per cent of absorption," are the averages obtained from five specimens, unless otherwise noted.

TABLE SHOWING RESULTS OF TESTS OF PAVING BRICK OBTAINED AT THE LABORATORY OF THE HIGHWAY DIVISION OF THE MARYLAND GEOLOGICAL SURVEY.

Laboratory No.	Name and where manufactured.	Color.	Dimensions in inches.	Weight in lbs.	Per cent lost in rattler at the end of 1800 revs.	Total cross-breaking strength in lbs.	Modulus of rupture, lbs. per sq. inch.	Per cent of absorption in 48 hours.	Remarks. Date of test.	Remarks. Made for	Remarks. Sample selected by
1	Welch, Gloninger & Maxwell, Welch's Station, Pa.	Red.	9x4x3.5	10.0	27	11,700	1800	2.9	July 19, '00.	City Engr. of Balto.	C. E.
2	Welch, Gloninger & Maxwell, Welch's Station, Pa.	"	9x4x3.5	10.0	26	8,300	1300	2.0	"	"	"
3	Hamburg (wire cut), Hamburg, Pa.	"	8.1x3.8x2.4	5.8	50	7,243	1800	3.3	July 24, '00.	"	M.
4	Hamburg (repressed), Hamburg, Pa.	"	8.5x4x2.5	6.8	24.6	10,120	2200	3.4	Aug. 7, '00.	"	"
5	Mack Mfg. Co., New Cumberland, W. Va.	Buff.	9x4x3.2	10.7	35	15,110	2740	4.1	"	"	"
6	Mack Mfg. Co. (wire cut)	"	8.25x4x2.5	6.7	20	9,780	2158	3.95	Aug. 9, '00.	"	"
7	Manufactured for G. P. Montague, Washington, D. C.	Dark red.	8.4x4x2.6	6.0	22	6,920	1600	3.4	Aug. 8, '00.	"	"
8	Mack Mfg. Co. (repressed)	Buff.	8.4x4x2.6	7.1	18	10,030	2255	3.5	Aug. 9, '00.	"	"
9	Wanamaker, Baltimore, Md.	Dark red.	8.75x4x3.1	9.9	25.3	......	....	....	Sept. 10, '00.	"	"
10	Wanamaker, Baltimore, Md., "B"	"	8.75x4x3.1	9.1	37.6	......	....	....	"	"	"
11	Wanamaker, Baltimore, Md., "C"	"	8.75x4x3.1	9.0	32.3	......	....	....	"	"	"
13	Wanamaker, Baltimore, Md., "No. 1"	"	8.7x3.9x3.2	8.8	28.6	13,730	2660	....	Sept. 25, '00.	"	"
14	Wanamaker, Baltimore, Md., "No. 2"	"	8.75x3.9x2.6	7.5	28.7	15,550	3450	....	"	"	"
15	Wanamaker, Baltimore, Md., "No. 3"	"	8.8x4x3.1	10.0	28	17,800	3220	....	Sept. 27, '00.	"	"
16	Wanamaker, Baltimore, Md., "No. 4"	"	....	9.7	25.4	19,730	3213	....	"	"	"
17	Welch, Gloninger & Maxwell, Welch's Station, Pa.	Red.	9.1x4.1x3.5	10.4	18.6	13,000	1952	2.6	"	"	C. E.
19	Higley, Keplinger & Co., Canton, O., "Canton Block"	Dark red.	8.6x4.0x3.4	9.7	18.6	19,460	3186	...	Sept. 28, '00.	"	M.
21	*Welch, Gloninger & Maxwell	Red.	9x4x3.5	10.0	22.3	......	....	....	Oct. 2, '00.	"	"
22	Higley, Keplinger & Co., Canton, O., "Iron Rock Block".	Dark red.	8.5x4x3.4	9.6	16.2	19,110	3100	1.6	Oct. 3, '00.	"	"
24	Johnsonburg Vitrified Brick Co., Johnsonburg, Pa. (repressed)	Red.	8.6x4.1x2.4	6.9	23.2	12,580	2744	1.7	"	"	"
25	Johnsonburg Vitrified Brick Co., Johnsonburg, Pa. (not repressed)	"	8.7x4x2.6	7.5	26.6	11,400	2450	4.6	Oct. 4, '00.	"	"
27	Frederick Brick Works, Frederick, Md.	Light red.	8.6x4.1x2.4	6.2	48.7	8,890	1960	9.5	Oct. 6, '00.	"	"
28	Clearfield Clay Co., Clearfield, Pa. (wire cut blocks)	Buff.	9.25x3.9x9.25	8.9	26.1†	12,613	2221	1.8	Jan. 2, '01.	"	C. E.

* Sample for St. Paul Street.

† Average of 15 tests. Max., 31.2%, min., 22.2%.

C. E. = City Engineer of Baltimore.
M. = Manufacturer.

TABLE—CONT'D. RESULTS OF TESTS OF PAVING BRICK OBTAINED AT THE LABORATORY OF THE HIGHWAY DIVISION OF THE MARYLAND GEOLOGICAL SURVEY.

Laboratory No.	Name and where manufactured.	Color.	Dimensions in inches.	Weight in lbs.	Per cent lost in rattler at the end of 1800 revs.	Total cross-breaking strength in lbs.	Modulus of rupture, lbs. per sq. inch.	Per cent of absorption in 48 hours.	Date of test.	Remarks. Made for	Sample selected by
29	Montello Brick Co., Reading, Pa.	Red.	8.4x4.0x2.7	7.4	19.2	11,605	2328	2.7	Oct. 27, '00.	City Engr. of Balto.	M.
30	Eastern Paving Brick Co., Catskill, N.Y. ("Catskill Block")	"	9.3x4.0x3.2	9.7	26.4	13,460	2328	1.3	Oct. 30, '00.	Mayor of Annapolis.	C. E. A.
32	Welch, Gloninger & Maxwell, Welch's Station, Pa.	"	9.2x4.1x3.0	8.9	21.2*	14,148	2556	2.1	Jan. 5, '01.	City Engr. of Balto.	M.
33	Clearfield Clay Co., Clearfield, Pa. (repressed)	Buff.	9.0x4.1x3.0	8.7	21.5	14,467	2562	....	Jan. 14, '01.	"	"
34	"Townsend Block," Zanesville, O.	Dark red.	9.1x4.1x3.0	8.8	21.6	18,313	3344	....	"	"	"
35	"Guise Block," Williamsport, Pa.	Red.	9.0x4.1x3.1	9.2	24.6	16,716	2930	....	Jan. 15, '01.	"	"
36	"Mack Block," New Cumberland, W. Va.	Buff.	9.25x4.0x3.2	9.3	17.6	14,234	2465	....	"	"	"
37	"Porter Block," New Cumberland, W. Va.	"	....	6.7	33.6†	......	....	....	"	"	"
38	Hamburg (repressed pavers), Hamburg, Pa.	Red.	....	6.6	55.8†	......	....	....	"	"	"
39	Mack Mfg. Co. (wire cut, not repressed)	Buff.	....	6.6	23.1‡	......	....	....	Jan. 16, '01.	"	"
40	Mack Mfg. Co. (repressed pavers)	"	....	7.2	17.0‡	......	....	....	"	"	"
41	"Mack Block," New Cumberland, W. Va.	"	9.25x3.9x3.1	9.2	18.0§	......	....	....	Jan. 25, '01.	"	C. E.
42	"Canton Shale Pavers," Canton, O.	Dark red.	8.7x3.8x3.4	9.3	19.8	......	....	....	Jan. 19, '01.	City Engr. of Balto.	M.
43	"Iron Rock Block," Canton, O.	"	8.5x4.0x3.4	9.8	16.3	......	....	....	"	"	"
44	"Guise Brick Pavers," Williamsport, Pa.	"	8.4x4.2x2.6	7.5	34.2	......	....	1.9	"	"	"
45	"Athens Block," Athens, O.	"	9.0x4.0x3.2	9.2	20.0	......	....	1.9	Jan. 21, '01.	"	"
46	‖Montello Brick Co., Reading, Pa.	Red.	....	7.0	26.1	......	....	....	"	"	"
47	‖Montello Brick Co., Reading, Pa.	Dark red.	....	7.0	21.2	......	...	2.6	"	"	"
48	"Nelsonville Block," Nelsonville, O.	Dark brown.	9.2x4x3.3	9.8	18.7	......	....	1.3	Jan. 22, '01.	"	"
49	"Johnsonburg Pavers," Johnsonburg, Pa.	Red.	8.6x4.1x2.3	7.0	21.2	13,398	3158	2.5	Feb. 12, '01.	"	"
50	"Johnsonburg Pavers," Johnsonburg, Pa.	Light buff.	8.6x4.25x2.4	7.3	21.1	12,593	2626	4.6	"	"	"
52	"¶Porter Block," New Cumberland, W. Va.	Buff.	9.25x4.0x3.25	8.9	22.5	......	....	....	Feb. 15, '01.	"	"
53	¶McMahon, Porter & Co., New Cumberland, W. Va.	"	8.5x4.0x2.2	6.5	50.0	......	...	....	"	"	"
55	Welch, Gloninger & Maxwell, Pa.	Light buff.	8.2x3.9x2.4	6.1	29.9	10,142	2572	1.1	Mar. 16, '01.	"	"
56	Queen City Brick & Tile Co., Cumberland, Md.	Red.	8.8x4.2x3.3	9.9	34.0	14,709	2324	2.5	Mar. 25, '01.	Mayor of Cumberl'd.	"

* Average of 6 tests.
‡ Tested with other brick. Not enough brick for test.
‖ 5 Brick of No. 46 and 10 of No. 47 were tested together.
† Tested together. Not enough brick for separate tests.
§ From car load. Average of 4 tests.
¶ Only 5 brick of each tested together.
C. E. = City Engineer of Baltimore.
M. = Manufacturer.
C. E. A. = City Engineer of Annapolis.

TABLE —CONT'D. RESULTS OF TESTS OF PAVING BRICK OBTAINED AT THE LABORATORY OF THE HIGHWAY DIVISION OF THE MARYLAND GEOLOGICAL SURVEY.

Laboratory No.	Name and where manufactured.	Color.	Dimensions in inches.	Weight in lbs.	Per cent lost in rattler at the end of 1800 revs.	Total cross-breaking strength in lbs.	Modulus of rupture, lbs. per sq. inch.	Per cent of absorption in 48 hours.	Remarks. Date of test.	Remarks. Made for	Remarks. Sample selected by
57	"Iron Rock Block," Canton, O.	Red.	8.6x3.9x3.6	10.1	15.6*	17,182	2888	....	Mar. 23, '01.	City Engr. of Balto.	C. E.
58	"Iron Rock Block," Canton, O.	Dark red.	8.5x3.9x3.5	10.0	17.4†	14,278	2430	....	"	"	"
59	"Iron Rock Block," Canton, O.	Red.	8.5x3.9x3.5	10.2	17.7*	19,012	3191	....	Apr. 22, '01.	"	"
60	McAvoy & Co., Pa. (Blocks)	Light red.	8.8x3.8x3.0	9.7	24.2	12,703	2596	1.4	Apr. 29, '01.	"	M.
61	McAvoy & Co., Pa.	"	8.3x3.9x2.6	7.1	29.8	13,028	3000	1.2	May 1, '01.	"	"
64	"Mack Block," New Cumberland, W. Va.	Buff.	9.2x4.0x3.2	9.4	21.6	.....	....	....	May 29, '01.	City Engr. of An'p's.	C. E. A.
67	"Guise Block," Williamsport, Pa.	Light red.	9.1x4.1x3.2	9.7	30.9	13,710	2337	....	June 22, '01.	City Engr. of Balto.	C. E.
68	"Iron Rock Block," Canton, O.	Red.	8.4x4.0x3.6	10.0	18.2	17,530	2887	....	June 25, '01.	"	"
69	"Mack Block," 15 tests — Mean	......	....	....	22.2	11,405‡	2108‡	....	....	"	"
	"Mack Block," 15 tests — Max	Buff.	....	....	26.1	......	....	....	1901.	"	"
	"Mack Block," 15 tests — Min	......	....	....	19.4	......	....	....	....	"	"
84	"Iron Rock Block," 20 tests — Mean	......	....	....	17.0	18,674§	3112§	....	....	"	"
	"Iron Rock Block," 20 tests — Max	Red.	....	....	20.1	......	....	....	1901.	"	"
	"Iron Rock Block," 20 tests — Min	......	....	....	15.2	......	....	....	....	"	"
108	"Iron Rock Block"	Red.	....	....	17.2†	......	....	....	Oct. 28, '01.	"	"
109	"Maxwell Block"	"	....	....	22.1	......	....	....	Oct. 29, '01.	"	"
110	"Maxwell Block"	Buff.	....	....	30.9	......	....	....	"	"	"
111	"Guise Block"	Red.	....	....	23.5†	......	....	....	"	"	"
113	"Porter Block"	Buff.	....	....	24.5†	......	....	....	Sept. 28, '01.	"	"
114	"Maxwell Block"	Red.	....	....	21.9†	......	....	....	Oct. 29, '01.	"	"
116	"Townsend Block"	"	....	....	23.7†	......	....	....	Sept. 28, '01.	"	"
117	"Montello Block"	"	....	....	18.7†	......	....	....	Oct. 10, '01.	"	"
120	"Mack Block"	Buff.	....	....	20.6†	......	....	....	"	"	"

* Average of 3 tests.
† Average of 2 tests.
‡ Average of 21 brick.
§ Average of 20 brick.

C. E. = City Engineer of Baltimore.
M. = Manufacturer.
C. E. A. = City Engineer of Annapolis.

CEMENT TESTS.

A machine for making tests of cement, a picture of which is shown in Plate XV, Fig. 1, was purchased and set up in the laboratory of the State Geological Survey. Before this machine was obtained the equipments at the laboratories of Harvard University, the Massachusetts Institute of Technology, Columbia University, the office of the State Engineer at Albany and the City Engineer's Department of Philadelphia were carefully inspected. The machine here shown was selected as the best for the work required in this laboratory; it is similar to one used at the Massachusetts Institute of Technology, which was designed by Professor Edward Miller of that Institute. In making a test, small briquettes are made of the cement, having a shape something like a dumb-bell, and the tensile force necessary to break them is measured by the machine. The principle of the machine is that of ordinary weighing scales used for fairly heavy weights; the force to be measured, reduced in a definite proportion by a system of levers, is balanced by a weight moving along a final beam. In many testing machines the weight hangs freely on the beam and jars are produced when moving it which interfere materially with the accuracy of the test. The special characteristic of this machine lies in the device for avoiding these jars. The weight is a brass wheel which rolls along the weighing beam; it is connected at its axle, by two hinged shafts, to an indicator, which slides on a fixed graduated beam. A movement of the indicator moves the wheel along the beam, but produces no sudden increase or decrease of the tension on the briquette.

The graduated beam has four scales, to each of which corresponds a particular wheel, supplied with the machine. The scales run respectively from 0 to 250, 500, 1000, and 2000 pounds. By replacing any special wheel by another whose weight is 2.2 times as much, the corresponding scale will read in kilograms instead of pounds. In making the test, the force is applied by hand or by power, and measured by the position of the indicator, which is moved so as to keep the weighing beam balanced. The machine works very smoothly and accurately.

At the request of Messrs. Baldwin and Pennington, architects, tests were made of several brands of cement offered for use in the

new State building at Annapolis. The complete tests consisted of the determination of the fineness, time of setting, and tensile strength of the cement. The briquettes for the last-mentioned test were made up of one part of cement and two parts of standard quartz sand. They were allowed to stay in the mould under a damp cloth for one day and were then removed and placed in water, where they remained until tested. Some of the briquettes were broken and their strength determined six days later, others after 28 days. The object of this is to determine if the cement sets and obtains its full strength very quickly or only after some time. Of the samples of cement tested, some were selected by the manufacturers and some were bought in the open market. In one or two instances the samples bought were markedly inferior to samples of the same brand submitted by the manufacturers.

A series of tests have been made to determine the relative strengths of cement mortar made up of different proportions of cement and sand, cement and limestone screenings, and cement, sand and limestone screenings. The object of this investigation was to determine what influence was exerted on the strength of the mortar by the sand and limestone screenings respectively. The work was undertaken at the suggestion of Mr. Wm. Keller, of Frederick, who furnished the materials for making the tests. The cement used was Dyckendoff's German Portland, the sand was from the Potomac river, and the screenings of Frederick county limestone. The strengths were determined after the briquettes had been one day in air and six days in water.

COMPARATIVE TENSILE STRENGTH OF BRIQUETTES MADE OF CEMENT, SAND AND LIMESTONE SCREENINGS MIXED IN DIFFERENT PROPORTIONS. SEVEN DAYS TEST.

Proportions by weight of			Strength in lbs. per sq. in.
Cement.	Limestone Screenings.	Potomac River Sand.	
1	0	0	493
1	1	0	291
1	0	1	217
1	2	0	208
1	0	2	129
1	3	0	157
1	0	3	108
1	1	1	209

FIG. 1.—MACHINE FOR TESTING THE TENSILE STRENGTH OF CEMENTS.

The Friedenwald Co.

FIG. 2.—MACHINE DESIGNED BY THE HIGHWAY DIVISION FOR MAKING CROSS-BREAKING TESTS ON PAVING-BRICKS.

TESTING MACHINERY.

The densities of the materials were determined by filling a carefully measured box with the cement, sand and limestone screenings, by dropping them from a height of three feet and leveling the top of the box with a straight edge. The contents of the box were then weighed and the densities found to be as follows: sand 1.60, cement 1.54, limestone screenings 1.51, showing that the sand is a little denser than the other two. The difference, however, is small and the results would have been practically the same if the proportions given in the above table had been by volumes instead of by weights. The table gives the average for a number of specimens in each case. It will be noticed that the pure cement is much stronger than any of the mixtures, and that the mortars made with limestone are stronger than those made with sand. There are two reasons for this: First, on account of the lime of which the cement is partially composed, there is probably a much closer cohesion with the limestone screenings than with the quartz sand. Second, the limestone screenings, used in these tests, are composed of finer particles than the sand, as will appear from the following table which shows the relative percentage of the limestone screenings and of sand that will pass through sieves with meshes of various sizes. Seventy per cent of the limestone screenings and 92 per cent of the sand, are stopped by a sieve of 50 meshes to the inch; while 83 per cent of the screenings and 99 per cent of the sand are stopped by a sieve of 100 meshes to the inch; although nearly 90 per cent of the Portland cement passes through the latter

TABLE SHOWING RELATIVE FINENESS.

Meshes per linear inch of the sieves.	Meshes per sq. in. of the sieves.	Per cent remaining on the sieves of		
		Dyckendoff German Portland Cement.	Potomac River Sand.	Limestone Screenings.
8	64	....	0	0
16	256	....	9.5	28.1
50	2500	0.3	82.4	42.0
74	5476	3.9	6.5	10.1
100	10,000	6.9	0.8	2.8
Passing 100	Passing 10,000	88.9	0.8	17.0
		100.0	100.0	100.0

TESTS OF MACADAM MATERIALS.

The methods of determining the qualities of macadam materials and the results of many tests are given in our first report.[1] A number of later results are given a few pages further on.

In these tests the *relative* and not the *absolute* wearing qualities of the materials are determined, and it is important that the conditions to which the various materials are subjected in the tests should be as nearly the same as possible; or if any differences should occur that it should be possible to calculate what effect these have had on the result and to introduce the proper corrections. Experiments have been carried out which have shown where special precautions are necessary, or how corrections can be applied, so that the tests can now be made with greater ease and with greater accuracy.

Abrasion Tests.

In the abrasion test, 5 kilograms (11 pounds) of stone, broken to a size that will easily pass through a 2½ inch ring, are placed in an iron cylinder, shown in Plate XIII, Fig. 1, and rotated 10,000 times, and the amount worn off is measured. There are usually about 50 pieces of stone in the charge. It might happen that, in the preparation, the stone is broken into pieces a little larger or a little smaller than the average, and a greater or smaller number of pieces might make up the 5 kilograms. On the other hand, it sometimes happens that the amount of the sample to be tested is not sufficient to make 5 kilograms of broken stone of the proper size. A series of experiments was undertaken to determine what effect such variations in the charges would have on the results. Two stones were selected, a hard diabase and a medium-grade limestone, both of very even texture, and many tests were made with each; first varying the sizes of the stones, but always using the same weight, 5 kilograms, and later keeping the sizes of the stones the same but varying the quantity. The results of these tests were indefinite. One sample would give a greater wear and another a smaller wear under the same modifications of the conditions, and it was not possible to determine any general law governing the action. The conclusion therefore is that, in making this test,

[1] Highways of Maryland, pp. 319-330.

the same quantity of stone, 5 kilograms, and as nearly as possible the same number of pieces should always be used. When sufficient stone (8-10 kilograms) is at hand there is usually no difficulty in selecting between 48 and 52 pieces to make up the proper weight to within 5 grams, which is quite close enough.

In this test it takes about 5 hours for the cylinders to be rotated 10,000 times. It was thought that this very long time could be reduced, and experiments were made to determine the relations between the amount of dust worn from the stone and the number of revolutions of the cylinder. The same two stones were selected as in the last set of experiments, namely, a diabase and a limestone. The method first tried was to stop the machine several times in the course of a complete test and take out the stones, clean and weigh them. They were then returned to the cylinder and the revolutions continued. After the 10,000 revolutions had been made it was found that the stones had suffered materially more abrasion than if they had not been cleaned during the course of the test. This was due to the removal of the dust, which clings to the stones and affords some protection from wear, and confirms the idea, already accepted, that a layer of dust is a protection to a macadam road. The method was then changed and the experiment carried on as follows: A charge of stone was put in the cylinder, rotated 250 times, removed and the abrasion determined. A fresh charge, but quite similar to the first, was subjected to 500 revolutions, a third to 1200, a fourth to 2000, a fifth to 3000, a sixth to 5000 and a seventh to 10,000. From 20 to 27 tests were made with each of the two kinds of stone, and the results plotted, as shown in the figure on page 126. A smooth curve was drawn through these points so as to make the errors a minimum. It will be seen that the rate of wear is greatest when the stones are fresh, which is due to the greater ease with which the edges and corners are broken off and to the small quantity of dust protecting the stone from sharp blows. A comparison of the two curves will show that the relative amounts worn off from the stones is nearly the same for an equal number of revolutions whatever that number may be. It is possible, therefore, to determine the coefficient of wear

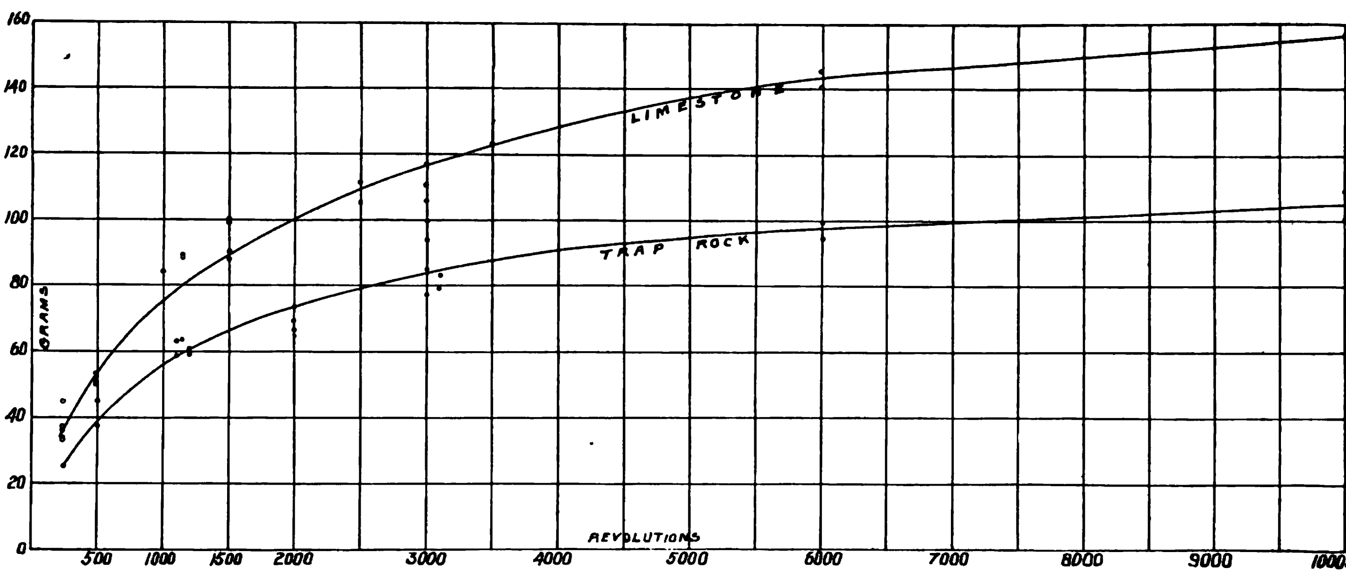


FIG. 3.—Curves showing rate of wear for soft and hard rock during the abrasion test.

RESULTS OF TESTS OF ROAD-METALS.[1]

Obtained by the Highway Division, Maryland Geological Survey.

TRAP ROCKS.

No. of Test.	County.	Scientific Name.	Common Name.	Coefficient of Wear.
175	Baltimore	Gabbro	Trap (or Nigger-head)	21.6
179	Baltimore	Gabbro	Trap (or Nigger-head)	12.7
189	Baltimore	Gabbro-diorite	Trap (or Nigger-head)	18.2
190	Baltimore	Gabbro-diorite	Trap (or Nigger-head)	14.6
192	Baltimore City	Gabbro-diorite	Trap (or Nigger-head)	20.5
198	Harford	Gabbro	Trap (or Nigger-head)	8.8
200	Harford	Gabbro	Trap (or Nigger-head)	7.3
202	Harford	Gabbro	Trap (or Nigger-head)	14.9
203	Howard	Gabbro	Trap (or Nigger-head)	13.5
207	Baltimore	Gabbro	Trap (or Nigger-head)	20.1
208	Harford	Gabbro	Trap (or Nigger-head)	15.1
209	Harford	Gabbro	Trap (or Nigger-head)	15.3

GRANITIC AND QUARTZITIC ROCKS.

No. of Test.	County.	Scientific Name.	Common Name.	Coefficient of Wear.
174	Baltimore City	Quartz-schist	Gneiss	12.3
176	Baltimore City	Gneiss	Gneiss	14.8
177	Baltimore City	Gneiss	Gneiss	17.6
178	Baltimore City	Gneiss	Gneiss	16.8
181	Baltimore	Quartz-schist	Sandstone	1.7
182	Baltimore	Quartz-schist	Sandstone	5.2
187	Baltimore	Gneiss	Gneiss	11.0
188	Howard	Granite	Granite	6.7
193	Baltimore	Gneiss	Gneiss	13.7
199	Harford	Gneiss	Granite	10.8
201	Harford	Granite	Granite	10.3
204	Howard	Granite	Granite	6.8
205	Howard	Gneiss	Blue gneiss	12.4
206	Howard	Gneiss	Black gneiss	13.1

LIMESTONES.

No. of Test.	County.	Scientific Name.	Common Name.	Coefficient of Wear.
180	Baltimore	Crystalline limestone	Limestone	9.3
183	Baltimore	Slag	Slag	9.4
184	Washington	Shenandoah limestone	Limestone	11.5
185	Delaware	Dolomite	Limestone	11.0
195	Baltimore	Slag	Slag	7.0
196	Baltimore	Magnesian limestone	Marble	3.6
197	Baltimore	Magnesian limestone	Marble	7.5

[1] Continued from previous report, p. 329.

with fewer revolutions than 10,000; for example, if the amount of dust formed by a certain sample, in 6000 revolutions is 129 grams, or nine-tenths of that formed by the limestone, then it would form nine-tenths as much dust as the limestone in 10,000 revolutions, and its coefficient of wear would be ten-ninths that of the limestone. It is not well to use too small a number of revolutions for this test, for in the first part of the curves they rise quite rapidly, and the various tests show large variations; but from four or five thousand revolutions onward the curves do not change rapidly, and tests made with other stones, but not plotted on this diagram, show a greater uniformity in this part of the curves.

These curves show the advantage of thoroughly rolling the stones placed on a road, so that the pieces may be held firmly in place and present a smooth side to wear; the rate of abrasion is then represented by the right hand part of the curves; whereas, if they are left loose they will be knocked about and have their corners broken off and be worn out much more quickly; the rate of abrasion in this case is represented by the left hand part of the curves.

Cementation Tests.

The determination of the cementation power of rock-dust was described in the first report and a description and figure of the machine used was given.[1] The method consists in making a cylindrical briquette, 25 mm. high and 25 mm. in diameter, of the dust produced during the abrasion test, or made especially for the purpose, and counting the number of blows of an automatic hammer necessary to break the briquette. There are several causes which may affect the result of this test, namely, variations in the height of the briquette, in the pressure applied in making it, in the quantity of water used, in the size of the dust particles, and in the force of the blow. It was very easy, by a little care, to prevent errors from the first three causes and attention was given to the effects of the last two. Briquettes made with dust particles of slightly different sizes showed a marked difference in strength, the finer particles making the stronger briquette.

[1] Highways of Maryland, p. 322.

Differences between the cementation values of some trap rocks obtained by the Massachusetts Highway Commission and by this office led to the following experiments. A quantity of dust was made from a certain trap rock, and after thorough mixing was divided into two parts; one part was sent to the Massachusetts Highway Commission and the second part retained. The part retained was passed through the sieve and made into briquettes in the usual way. Half of these briquettes were tested here and half sent to Massachusetts. The dust sent to Massachusetts was likewise passed through the sieve there and made into briquettes, half of which were tested there and half were sent to Baltimore. The briquettes made of dust which passed through the sieve here, gave practically the same results whether they were made or tested here or in Massachusetts; whereas, the briquettes made from dust which passed through the Massachusetts sieve gave results different from the former. It is clear, therefore, that there is a difference in the average size of the particles passing through these two sieves respectively, sufficient to affect the results of this test, although the attempt was made to have the sieves just alike; and it is also shown that the other conditions of the test are in good accord in the two laboratories.

A microscopical examination of the dust made in the usual abrasion test, and of that made when pieces of iron are added to increase the quantity, shows a distinct difference in the size of the particles and the briquettes made from them show a difference in strength.

It is therefore important that some standard method be devised to make the dust. It is not sufficient to make the sieves exactly alike, although this should be done, but it is also necessary that the dust should be prepared in a uniform manner, for there is a marked difference in the sizes of dust particles which pass through a sieve with meshes as small as it is practical to use. After consultation with Mr. L. W. Page,[1] a ball-mill has been adopted for preparing the dust in a uniform manner. A diagram of the machine is shown in the figure on page 130. It consists of a flat circular cast iron chamber 50 centimeters (20 inches) in diameter, and 12 centimeters ($4\frac{3}{4}$

[1] Formerly in charge of the laboratory of the Massachusetts Highway Commission, and now in charge of the Road Material Laboratory of the Department of Agriculture at Washington.

inches) wide, containing two cast steel balls of slightly smaller radius than that of the rim of the chamber where the balls lie. The balls weigh 11½ kilograms each. One kilogram of rock fragments, which will pass through a six millimeter opening but not through a one millimeter opening is put into the chamber and rotated for 2½ hours, making 5000 revolutions. The balls rolling over the rock fragments grind them to fine dust. This dust is passed through a sieve of three meshes to the millimeter (about 80 to the inch), and the briquettes are made of the dust passing through. The sieve is made of number

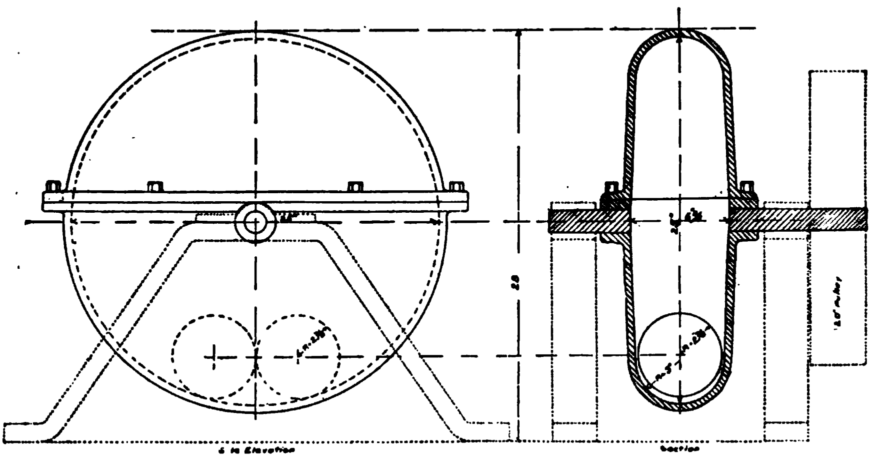


FIG. 4.—Sketch of ball-mill for making stone dust for the cementation test of macadam materials.

7 silk bolting cloth. This probably gives as uniform results as can be practically obtained. A ball-mill of this kind is now in use in the Road Material Laboratory at Washington and is giving satisfactory results; one will shortly be ready for the laboratory of the Maryland Geological Survey.

In determining the relative strength of briquettes, it is necessary that the blows delivered upon them by the automatic hammer be uniform, and uniformity can only be obtained by having the height through which the hammer falls accurately the same. As this height is only ten millimeters (2/5 of an inch) in order that the variation should not be greater than one per cent, the height of the blow must

be accurate to one-tenth millimeter (1/250 inch). The hammer-release on the machine formerly in use could not give such accurate results, and a new machine has been designed and made in the laboratory of the State Highway Division for the special purpose of overcoming this defect. It is essentially a modification of the original machine, but it is so arranged that in raising the hammer it is brought up against a fixed stop, at which point it is released, and thus the height of the fall can be very accurately gaged. In the former machine the hammer was raised by means of a rotating screw, and it was arranged for either very short or very long falls; this was considered unnecessary, and the new machine is only used for small falls, the hammer being raised by a cross-head, moved up and down by a circular crank on the top of the machine. The hammer weighs one kilogram and contracts at the top to a small rod, the head of which is enlarged and then beveled off to a conical surface. The catch of the cross-head takes hold of this enlargement and raises the hammer until it comes in contact with the fixed stop. The catch then slides over the enlargement, allowing the hammer to fall. The fixed stop is the end of a rod fastened by set screws at the top of the machine so that its position can be raised or lowered at pleasure. The blow is not delivered directly upon the briquette but through a steel cross piece, called the plunger, which rests on the top of the briquette. To this plunger is fastened a vertical measuring rod divided into centimeters. Fastened to the stop rod is an indicator which slides over the measuring rod as shown in Plate XIV, Fig. 2.

To measure the height of a blow a brass cylinder about equal in size to the briquette is placed under the plunger, the hammer is allowed to rest on the plunger and the stop rod is brought down against the head of the hammer. The indicator is then adjusted to read zero on the scale of the measuring rod and fastened firmly to the stop rod. If now the stop rod is raised so that the indicator marks one centimeter, a blow of that height will be delivered. If a briquette is then placed in position, whose height differs somewhat from that of the cylinder, the scale rod, moving with the plunger, will be slightly displaced. The stop rod must then be adjusted so that the

indicator will read one centimeter and the fall of the hammer will be accurately gaged. The number of blows necessary to break the briquette is recorded on a drum similar to that of the original machine. This machine seems to be in every way satisfactory, and a similar one has been made in this laboratory for the Road Material Laboratory at Washington. The old machine with some modifications is now used for impact tests, as described elsewhere.[1]

Great efforts have been made to standardize and render accurate the tests of macadam material, since equipments for making these tests are gradually being installed in various parts of the country, and it is a matter of importance that the tests made in different laboratories should be comparable among themselves.

Special Road Improvement.

ANNE ARUNDEL COUNTY.

South River Road.

In accordance with a law passed by the Legislature, the road between Camp Parole and South River Bridge has been improved under the charge of a special commission of which Dr. E. M. Elzey was chairman. The law directed that $4000 might be expended on this road, and that it should be raised by levy in equal parts from the 1st, 2nd, 6th, and 8th election districts; and that the work should be done by contract. The Commission requested the Highway Division to make an examination of the road. The conditions were entirely different from those prevalent on the roads heretofore examined, for the road was over an exçeedingly sandy soil for nearly its entire length and was much worse in dry weather than in wet. There were three sections of the road where the grades exceeded 6 per cent, running in places as high as 12 per cent. At the suggestion of the Highway Division the Commissioners made a request for a survey and detailed estimates and specifications for improving the road. In this connection inquiry was made as to the cost of broken stone delivered at Annapolis and Parole. It was found that gneiss could be delivered at Parole for $1.25 per ton of 2000 pounds; granite from Port Deposit could be had at the wharf at Annapolis at a cost of $1.35 per ton; slag

[1] Page 115.

from Sparrows Point on the car at Annapolis for 85 cents per ton. The Commission was advised to use slag if sufficient money was at hand. It was estimated that for a road 10 feet wide and 6 inches thick about 1300 tons of slag per mile would be required. In May, 1900, the survey of the road was made and plans, estimates, and specifications furnished the Commissioners.

They adopted the plans of the Highway Division and the road was built during the summer of 1900. At Beaver Dam Creek, where a large fill was made, much difficulty was experienced owing to the yielding of the soil when the weight of the embankment was put upon it. Additional earth was necessary to bring the fill up to grade. At the present time, November, 1901, no further settlement seems to have taken place. After a number of attempts the contractor abandoned the construction of a box culvert at this point and substituted 30-inch pipe, which was finally laid after a great deal of trouble. The fund available was not sufficient to surface the road with slag and the Commissioners decided to use shells for the whole road from South River Bridge to Camp Parole, with the exception of a distance of about a third of a mile, which was already in good condition. This required 38,334 bushels of shells, which were bought at a very advantageous price. Mr. E. Lacy Chinn, County Surveyor of Anne Arundel county, had charge of the construction.

An inspection of the road was made in the early part of November, 1901, and it was found to be in fair condition. The greatest difficulty has been experienced with the horse track, which forms especially on the hills, allowing the water to collect and run down the middle of the road, and where it finally runs over the sides at the bottom it causes much trouble by washing the embankment. A view of the finished road is shown in Plate XVI, Fig. 1. The picture shows a part of the road where the grades, which were from 10 to 12 per cent, have been reduced to 6 per cent; the horse tracks can be plainly seen.

Baltimore-Annapolis Road.

Much interest had been shown by some members of the Legislature in the improvement of the road between Baltimore and Annapolis, a road which is very much used. The Highway Division in December, 1899, made a survey and drew up plans and estimate for the improve-

ment of 4.2 miles of this road from Brooklyn to Sawmill Branch, which were exhibited to the Legislature of 1900, because it was expected that that body would take some action for the improvement of the road, and also as an example of the engineering required for the proper economical construction of roads. The improvement planned contemplated the reduction of the present grades to 4 per cent, with the exception of about 1000 feet on the hill to the south of Holy Cross Cemetery, where the present grade of 5.3 per cent was not to be changed. The largest amount of excavation would be required at Norris Hill, where present grades are as high as 7 per cent. This hill had already been partially graded, 15,000 to 20,000 cubic yards having been cut from the top and used in grading the approaches on either side. To reduce the grade at this point to 4 per cent would necessitate further excavation of about 12,300 cubic yards. The total amount of grading as far as Sawmill Branch would require the excavation of about 22,800 cubic yards, extending over 1½ miles of road. A summary of the estimate for the improvement of this road is as follows:

Cost of surfacing with broken stone, 15 feet wide, 2.7 mile of road, which it is unnecessary to grade, at $3,500 per mile	$9,450.00
Cost of 1½ miles, grading and surfacing	9,060.00
Cost of culverts and drains	500.00
Estimate of total cost of 4.2 mile of road	$19,010.00

This brings the average cost per mile to about $4530. The above estimate was made on the assumption that broken stone would be used for surfacing. The cost of 1½ miles of road between Sawmill Branch and Glenburnie would be about $4000 per mile, making the total cost of the road from Brooklyn to Glenburnie about $25,000. Up to the present time nothing has been done.

A line of levels connecting the bench-marks in Baltimore and in Annapolis has been run following the Baltimore-Annapolis road as far as Glenburnie, and the line of the Baltimore and Annapolis Short-line railroad from there to Annapolis, and intervening bench-marks

FIG. 1.—CUT AT BEAVER DAM HILL ON SOUTH RIVER ROAD, ANNE ARUNDEL COUNTY.

The Friedenwald Co.

FIG. 2.—RUTS FORMED IN SHELL ROAD NEAR SALISBURY, WICOMICO COUNTY.

MARYLAND HIGHWAYS.

were established about every mile. For the benefit of those who may have occasion to run levels in the vicinity, descriptions and elevations of these bench-marks are added. The elevations are determined with respect to the datum plane of the Pennsylvania railroad, which is adopted by the U. S. Geological Survey. The three datum planes used in this neighborhood may be compared by giving the height of a chosen point when referred to each of them as follows:

Datum plane of U. S. Coast and Geodetic Survey.....124.053 feet.
Datum plane of City of Baltimore Topographic Survey.124.688 "
Datum plane of Pennsylvania railroad ....123.305 "

Description of Bench-marks between Baltimore and Annapolis. Elevations referred to Mean Sea Level, using datum plane of Pennsylvania Railroad.

No.	Description of Bench-marks.	Elevations in feet.
1.	Center of head of copper nail in N. W. corner of building occupied by Geo. Kahl, near N. end of Long Bridge in Baltimore. Nail is about 3.5 feet above porch floor	12.38
2.	Center of head of copper nail in a telephone pole about 100 feet S. of south end of Long Bridge near N. E. corner of First St. and Chesapeake St., Brooklyn	10.31
3.	South edge of top of brick foundation N. W. corner of house owned by Mewshaw, near N. E. corner First and Annapolis Sts., Brooklyn, about 100 yards N. of B. & O. R. R.	9.19
4.	Head of large wire nail in root of a poplar tree (about 2 feet in diameter) on W. side of Baltimore and Annapolis road, 150 feet S. of a cabin and about ¼ mile S. of road from Brooklyn to Pumphrey station.	63.09
5.	Head of copper nail in root of the southernmost tree of a clump of 3 small pine trees on E. side of Baltimore and Annapolis road, on top of a hill about ½ mile S. of road from Brooklyn to Pumphrey. Nail about 1.3 feet from trunk of tree	106.78
6.	Head of copper nail in water table S. W. corner of large yellow farmhouse on E. side of Baltimore and Annapolis road, on top of hill about 1½ miles S. of south end of Long Bridge. Nail about 1.2 feet above brick walk	161.18
7.	Northwestern corner of marble window-sill, S. side of gateway at entrance to Cedar Hill Cemetery, on E. side of Baltimore and Annapolis road.	153.19
8.	Head of large wire nail in top of a culvert end-wall, E. side of Baltimore and Annapolis road, about 100 feet S. of a blacksmith shop on W. side of road, 2000 feet S. of Norris Hill Park	67.50
9.	Northwestern corner of stone abutment, S. end of bridge over Sawmill Branch on Baltimore and Annapolis road. Cement coat-	

No.	Description of Bench-marks.	Elevations in feet.
	ing was cut away and corner of stone shaped like half a walnut; about same level as floor of bridge.............................	6.88
10.	Top of N. E. corner of lowest projecting brick of N. E. corner of brick store, W. side of Baltimore and Annapolis road and S. side of B. & A. S. L. R. R. at Glenburnie. B. M. about 3 feet above the ground.	57.53
11.	Center of head of copper nail in N. E. corner of small wooden bldg. at Marley station on W. side of B. & A. S. L. R. R. track. Nail about 1 foot above level of platform........................	58.28
12.	Center of head of copper nail in N. E. corner of building used for station at Elvaton on W. side of B. & A. S. L. R. R. tracks........	75.46
12A.	Head of large wire nail in root, E. side of an oak tree in front of store on S. side of B. & A. S. L. R. R. at Elvaton..................	72.47
12B.	Center of head of copper nail in S. E. corner of house 50 feet N. of store at Elvaton..	75.46
13.	Head of large wire nail in large stump at fork of Baltimore and Annapolis road and road to Elvaton station. Stump on N. side of Baltimore and Annapolis road and about 1 mile N. of Elvaton....	86.51
14.	Head of large wire nail in root of chestnut tree on W. side of B. & A. S. L. R. R. at Pleasantena, near road-crossing, and opposite switch. Tree is about 35 feet from track, has 3 trunks branching near the ground..	85.55
15.	Middle of head of copper nail about 4 feet above the ground in N. E. corner of store at Earleigh Heights or Frosts, on B. & A. S. L. R. R.	75.22
16.	Middle of head of copper nail about 6 feet above the ground in N. W. corner of store on E. side of B. & A. S. L. R. R. at Robinson station.	51.84
17.	Head of large wire nail in stump on E. side of Baltimore and Annapolis road, opposite road to Robinson station on B. & A. S. L. R. R. About ½ mile N. of station..................................	47.29
18.	Middle of head of copper nail in S. face of brick pier under S. E. corner of store at Jones station on W. side of B. & A. S. L. R. R..	66.68
18A.	Middle of head of copper nail in N. E. corner of small freight house on W. side of B. & A. S. L. R. R. at Jones station...........	66.37
19.	Middle of head of copper nail in W. face of brick chimney on S. side of store, on E. side of B. & A. S. L. R. R., at Arnold station or Asbury P. O. Nail 0.08 foot from S. face of chimney and 4.5 feet above the ground...	129.24
20.	Head of large wire nail (through a washer) in sill of E. pier of wooden bridge over the B. & A. S. L. R. R. about 200 feet N. of Winchester station. Nail is 6.1 feet from N. end of sill, about 0.4 foot from W. face, and about 3.4 feet above top of rail. Bottom of washer left flush with top of timber........................	79.05
21.	Head of large wire nail, through washer, driven in timber of cross-bent, 3rd from S. end of B. & A. S. L. R. R. bridge over Severn	

No.	Description of Bench-marks.	Elevations in feet.
	river. Bent is one just inside line of piling forming breakwater. Nail is in middle of timber 1.5 feet from E. end and about 2 feet below bottom of rail. Bottom of the washer flush with top of timber.	8.78
22.	Middle of head of copper nail in N. post of wooden bridge over B. & A. S. L. R. R. about 150 feet N. of West Annapolis station. Nail about 4 feet above top of rail	33.28
23.	Head of copper nail in brick wall near N. E. corner of office of Annapolis Electric Light Works at Annapolis. Nail 0.33 foot from E. face of projecting course of bricks and about 1.5 feet above the ground.	25.09
24.	Head of copper nail, flush with surface of brick, in N. W. corner of wall around the Navy Yard at Annapolis, on side facing King George St., near bridge over branch of the Severn. Nail 1.66 feet from N. face of wall, 0.8 foot above sidewalk. (Nail is bent.)...	7.27

BALTIMORE COUNTY.

New Road Law.

The special features of the new road law for Baltimore County, which was passed by the last General Assembly, are: The appointment by the County Commissioners of Road Commissioners who are to serve without pay, except $125.00 per annum for expenses, and the appointment by the Governor of a Roads Engineer to direct the improvements of the county roads. The Road Commissioners are to serve for two years, there being two or three to each district. The Roads Engineer must have the degree of Civil Engineer; his salary is $2000 per annum, with $500 for travelling and office expenses. He shall inspect the county roads, submit general plans for their improvement, and recommend such repairs and improvements as he may think advisable. He shall also make plans and specifications for special roads when called upon by the Road Commissioners, and shall make an annual report to the County Commissioners, and to the Maryland Geological Survey on the condition of the county roads and the improvements which have been made during the previous year. The Road Commissioners shall submit all bills to the Roads Engineer monthly, to be approved by him before payment. Improvements costing more than $100.00 may only be made after the submission of plans and specifications by the Roads Engineer;

and wherever stone to the amount of more than 100 perches is to be purchased, specimens must first be submitted to the State Geologist to be tested.

The road-tax is to be between 15 and 25 cents on the $100. Of this 5 cents must be set aside as a general road and bridge fund, and the remainder is to be expended in the district where collected. Two-thirds of the road-tax must be used in macadamizing the roads. In case the road-tax does not meet the expenses of the year, the County Commissioners may borrow as much as $20,000, which sum must be paid out of the levy for the following year. When certain persons are willing to make special contributions for the improvement of a special road, the County Commissioners may appropriate an equal amount from the general road and bridge fund and have the improvements made under the direction of the Road Commissioners.

This law went into effect January 1st, 1901. W. W. Crosby, C. E., for several years connected with the Massachusetts Highway Commission, was appointed Roads Engineer by the Governor. The benefit of the law has been evident from the skilled supervision given to the roads, and their consequent improvement. The improvement in the accounts of road expenditures is also marked. The full report of the Roads Engineer for the year 1901 will be found on pages 179-201.

Glencoe Roads.

The road leading westward from Glencoe station crosses the Big Gunpowder river and then divides into two, one running to the north and the other to the south. Both of these roads keep close to the river for some distance before turning to the west to join the York Turnpike. The parts of the roads along the river bank, about a mile in length, are subjected to frequent floodings. This section was formerly in very bad condition during the greater part of the year and in rainy weather it was so soft and sticky that it was almost impossible to drive over it. Stone had been put upon the roads but it had soon sunk into the mud with no permanent improvement.

The farmers in the neighborhood felt that these roads must be

improved. They contributed in money and labor the equivalent of about $543. The county added an equal amount, making about $1100 in all available for the roads. Mr. A. B. Gardner, Jr., had charge of the improvement and he asked for the assistance of the Highway Division. A survey was made and it was decided to raise the low parts of the roads about three feet. This would make it possible to drain them thoroughly in all weather. A small amount of retaining wall was necessary to hold the embankment at the approach to the bridge where much filling was required to reduce the former high grade. As the money at hand was only sufficient to improve the low parts of the roads near the river, the earth required had to be obtained outside the line of the work. The only earth at hand was river silt, which contained much finely divided mica, and made a soil which was almost a quicksand when wet, but when dry seemed to afford a fairly firm footing. To obtain better earth a long haul would have been necessary, which was out of the question with the money at hand.

To keep the road-bed dry, ditches were made and a number of cross drains put in. At one point there was a small amount of ledge jutting out into the road which it was necessary to remove. The stone was used for retaining walls and as a protection to the ends of drains. The plan was to use spalls from the limekiln at Texas for surfacing. Hopes had been entertained that the railroad would transport this at a very cheap rate, but only a small reduction in the regular freight rate could be obtained, while the price of the stone itself was more than was anticipated; therefore but few carloads of stone were used.

The work was done in November and December, 1899, under the direction of the Highway Division. The improvement has been of the greatest benefit to the farmers of the neighborhood as the road is now never muddy.

Govanstown Sidewalk.

The Neighborhood Improvement Club of Govanstown has been anxious to have a sidewalk built along York Road, through Govanstown. It is proposed to raise the money for this purpose in part

by entertainments to be given by the club and in part by subscriptions from those living adjacent to the road. Before proceeding with the work, the club requested the Highway Division to make plans and estimates of the cost of the improvement. Owing to the location of the electric car tracks on the eastern side of the road, the western side has been selected for the sidewalk. A survey of this side was accordingly made, showing location of fences, houses, gutters, drains, and car-tracks. Cross-sections have been prepared on which are shown the location for the proposed walk. By their aid property owners will be able to see exactly what change will be made in front of their premises and all disputes can be adjusted before the work is undertaken, in order that there may be no hindrance during construction. It is planned to build a walk five feet in width, with a cinder foundation, and surfaced with broken-stone screenings. The walk is to be raised one foot above the gutter, and to have a sodded edge two feet wide. The plans for this work have been made with the cooperation of the Roads Engineer, and it is expected the work itself will be undertaken in the spring.

Green Spring Valley Road.

A request for a survey of a portion of this road near Chattolanee station was made by Mr. W. W. Crosby, Roads Engineer for Baltimore county. The survey extended for about a mile from the station towards Park Heights avenue. It was suggested that a part of the road be relocated, in order to avoid an ugly bend in the present road and at the same time to improve the grade. The Roads Engineer, however, decided that this part of the work could not be undertaken at present with the funds at his disposal, but about three-fourths of a mile has been surfaced with Texas limestone.

Garrison Road.

A survey of the Garrison road, beginning at a point near Chattolanee station, on the Green Spring Valley road, and extending a short distance beyond Garrison Church, was also made at the request of the Roads Engineer. At present the grades on the hill approach-

ing the church are very steep, running as high as 13 per cent, and the road-bed is narrow. To reduce these grades to 5 or 6 per cent, however, would require a large amount of excavation, costing far more than could possibly be spent upon this road at present. It was, therefore, decided by the Roads Engineer, that all that could now be done would be to widen the road and to remedy to a small extent some of the steepest places. At other points on the road the grades have been changed to those recommended and the road has been surfaced for a width of fifteen feet with limestone from the Green Spring Valley.

HARFORD COUNTY.

The Woolsey Bequests.

The roads of Harford county had been the subject of much thought and attention on the part of the late William Woolsey, and upon his death in 1888 he left practically all of his property, amounting to about $55,000, dependent upon what may be realized for his farms and subject to a life interest in the income of the estate by his sister, Miss Rebecca Woolsey, for the improvement and macadamizing of certain county roads, the work to be done by the County Commissioners under the charge and direction of a competent civil engineer within five years of the time the money should become available; and he appointed John Moore, Alexander S. Bell, and Stevenson A. Williams trustees to carry out his wishes.

The order in which the roads should be improved and the times of payment of the money are described in the following extract from the will:

". . . . . . first the road from Belair to Churchville; second, the road from Churchville to Havre de Grace by way of either Avondale or Hopewell; third, the road from Churchville to Aberdeen by the station of the Philadelphia, Wilmington and Baltimore railroad; fourth, the road from Churchville to Darlington by way of Glenville and Wilsons Mill; fifth, the road from Churchville to Calvary Church; and upon the completion of said first-named road and the approval of the same as aforesaid by said trustees, then to pay over to the said County Commissioners the sum of Ten Thousand Dollars

($10,000) out of said trust fund, and upon the completion of said road named secondly above, and the approval thereof as aforesaid, then to pay over to the said County Commissioners the further sum of Twenty Thousand Dollars ($20,000), and upon the completion of said road named thirdly above, and the approval thereof as aforesaid, then to pay over to the said County Commissioners the further sum of Eight Thousand Dollars ($8000), and upon the completion of said road named fourthly above, and the approval thereof as aforesaid, then to pay over to the said County Commissioners the further sum of Fifteen Thousand Dollars ($15,000), and upon the completion and approval as aforesaid of said road named fifthly above, then to pay over to the said County Commissioners the further sum of Five Thousand Dollars ($5000).

"It is my will and desire that said roads shall be completed and paid for, as herein provided, in the order I have named them, so that in case the said trust fund shall not be sufficient to complete them all, those named latest shall fail in order beginning with the last; and I do not intend by the description I have given of said roads to confine the improvements to be made to the present location of each road if the County Commissioners and the Civil Engineer aforesaid think best to make changes in the location thereof; the description herein being merely intended to indicate the points to be connected by said roads, and the general direction in which it is to be done."

Miss Rebecca Woolsey died in January, 1901, and the bequest of her brother to the county then became available. She left about $6000 of her own property to the county for the improvement of certain other roads, viz., "The road from Rock Spring Church by way of Forest Hill to Grafton's Shops; second, the road from Fallston Station, on the Baltimore and Lehigh Railroad, to Waters' Cross Roads, and upon the completion of said first road and the approval of the same by said Trustees, then to pay over to the County Commissioners, $1750; and upon the completion and approval of the second named road, $3000, and the balance of said trust fund shall pass over to themselves or successors for the time being, under the last will and testament of my brother, William Woolsey, so that the

FIG. 1.—BEFORE IMPROVEMENT.

The Friedenwald Co.

FIG. 2.—AFTER IMPROVEMENT.

BELAIR-CHURCHVILLE ROAD.

same may be applied as directed by said will for the benefit of the county roads therein referred to." The trustees named by her were the same as those named by her brother.

Belair-Churchville Road.

On January 7, 1900, the County Commissioners accepted these bequests and appointed George T. Maynadier and William H. Harlan to represent them in the construction of the Belair-Churchville road, and suggested that they, with the other trustees, form a board of five managers and assume complete charge of the construction of this road. This committee met and organized as the Woolsey Road Commission and applied to the Highway Division of the Maryland Geological Survey for advice and assistance. The Highway Division offered to make the necessary surveys, to prepare plans, specifications, estimates and forms of contract for the work and to undertake general supervision during the construction. The Committee gladly availed themselves of the offer. The surveys were completed and estimates furnished during May, 1901.

The total length of the road surveyed extending from Belair to Churchville is 5.47 miles. For a large part of this distance the road has been at various times covered with broken stone, which in many places has become compacted and makes a fair road-surface; much of the surface, however, was very rough. There was a bad hill about three-quarters of a mile from Belair having long grades of 9 and 10 per cent and, for a short distance, a grade of 13 per cent, and there are a number of short steep slopes in other parts of the road with grades of 7 or 8 per cent.

After thoroughly studying the conditions of the road the Highway Division recommended that the long hill near Belair be reduced to grades of 5 and 6 per cent, which would require about 2300 cubic yards of excavation, and that the short grades in other parts of the road be also reduced, requiring about 1400 cubic yards of excavation. It was also recommended that about 1¼ miles of telford and a little more than 2 miles of macadam be laid to a breadth of 12 feet, thus making 3⅓ miles of improved roadway. The remaining distance, a little less than 2⅓ miles, which already had a firm and hard

foundation and no heavy grades, could be left untouched for the present. It was also recommended that the work be done by contract.

These plans with small modifications were accepted and the County Commissioners advertised for bids according to the specifications of the Highway Division.[1] On June 18, the three bids which had been submitted, were opened. Two were for the whole work and one for the first two sections. The lowest bid for the whole was $18,000 and, as this was much more than it was possible to pay, all the bids were rejected. It was evident that the contractors had misunderstood some of the items, and it was thought that after they had acquainted themselves more fully with the requirements, lower bids could be obtained. After considerable delay the contract was finally awarded to Charles A. Hook and Son, of Baltimore, the total amount of their bid coming very close to $13,000. The cost per mile of road actually to be built, about $3900, is considerably higher than would be the average cost if the road had been built for the entire distance, inasmuch as the sections upon which work has been planned include the worst portions of the road and those on which it was necessary to do heavy grading.

The work is now being done under the supervision of the Highway Division of the State Geological Survey, and at the present time nearly all the grading has been completed, and over a mile of the telford foundation has been laid and rolled, just east of Bynum's Run. The first course of broken stone has been put upon the telford and this portion of the work is fast nearing completion. Where telford foundation has not been used, macadam has been laid upon the earth foundation after a thorough rolling of the latter.

The stone used for surfacing was obtained from the neighborhood; some was field stone and some came from quarries. The tests of these stones are given in the table on page 127. The numbers are 202, 208, 209. It will be seen that they are all hard stones.

The work was at first considerably delayed on account of the small amount of stone which was crushed each day. A few yards east of Mr. Oldfield's mill about 300 feet of 6-inch drain pipe has been

[1] A copy of the specifications is given on pp. 168-175.

laid in the center of the road to carry off the underground water, which at this point made the road extremely soft in wet weather, in spite of the stone which had already been put upon it. When the ditch for this pipe was opened a number of springs were found from which water was still running at the end of a protracted dry season. Around the pipe broken stone has been laid, and it is thought that all trouble from this source has been removed. Plate XVII, Fig. 1, shows a portion of this road before improvement. A view from the same point of the nearly finished road is shown in Plate XVII, Fig. 2. The change in the grade on the first hill can be seen in Plate XVIII, Fig. 1.

The Highway Division emphasized the importance of having a steam-roller used on the work, and the County Commissioners decided to obtain one. The machine purchased is a double cylinder ten-ton roller manufactured by Wm. C. Oastler of New York; the price paid was $2650. If the roller had not been supplied by the County Commissioners it would have been very hard to find a contractor near at hand who could undertake the work, owing to the fact that no one of them in this neighborhood owned a roller.

Archer's Hill Road.

The County Commissioners of Harford county had been petitioned to have the hill known as Archer's Hill cut down or the road relocated so as to avoid it. This hill is on the direct road from Deer Creek southward toward Churchville, and is an important county road. The Commissioners appointed examiners, and to aid the examiners in their report they requested the Highway Division to make an estimate of the cost of various proposals which had been entertained. The alternatives considered were cutting down the grade of the present road, which in some places is as steep as 15 per cent, or the relocation of the road along one of several suggested routes. The necessary surveys were made in June, 1900, and it was found that by far the cheapest method to avoid the steep grades was to relocate a portion of the road by a short detour to the east. By this change no grade exceeding 6 per cent would remain; about 1500 feet of new road would be required, and about 1200 feet of the old road would

be abandoned. The approximate cost, including the damage done by cutting off seven acres of land from a field, and the purchase of the one acre of land occupied by the road itself, would be about $600. Owing to the lack of funds available for this work, nothing has yet been done.

HOWARD COUNTY.

Old Frederick Road.

In August, 1900, the County Commissioners of Howard county wished to improve a portion of the Old Frederick road between Davis lane and the Marriottsville road. Before starting the work they requested the Highway Division to examine the road and to furnish them with a detailed estimate of the cost of improving it. By far the worst portion was that near the Marriottsville road, where there were steep grades of from 8 to 13 per cent extending for 525 feet. Moreover, this part of the road was narrow and made an ugly turn. A survey was made and a plan and profile of the road from Davis lane to the Marriottsville road were drawn, showing the old road and also the proper relocation of about 600 feet near the Marriottsville road. The Commissioners were strongly urged not to consider surfacing until the steep grades had been removed, and if there was insufficient money for both, to apply what there was towards grading. To reduce the grade so as not to exceed 5 per cent would require excavating 3073 cubic yards, of which 600 yards were thought to be ledge. The estimated cost of the work was 25 cents per cubic yard for the earth, or $618.25, and $1 a cubic yard for the ledge, or $600, making the total cost of excavation $1218.25. To make the proper grade it was necessary to raise the surface about 6 feet at the Marriottsville road. The amount of money the Commissioners had on hand for the work was only $1000 and they did not wish to begin the work until they could finish it completely, so they decided to put it off until the following year, when $1000 more would be available. The work was taken up in the summer of 1901 and the grading was let by contract in the manner described on page 105 for the sum of $1225, the contractor being Michael Cooney of Howard county. This work

FIG. 1.—EMBANKMENT MADE AT FOOT OF BELAIR HILL, BELAIR-CHURCHVILLE ROAD, HARFORD COUNTY.

The Friedenwald Co.

FIG. 2.—OLD AND NEW LOCATION OF OLD FREDERICK ROAD NEAR THE MARRIOTTSVILLE ROAD, HOWARD COUNTY.

(EMBANKMENT OF NEW LOCATION AT THE EXTREME RIGHT.)

ROAD IMPROVEMENTS.

was carried out in accordance with the plans of the Highway Division.

As the work progressed additional marks and suggestions were given the contractor to aid him in bringing the road to the proper grade. The Commissioners decided to surface the road with a soft variety of quartz schist which could be easily obtained nearby. This was placed on the road and broken with hammers at a cost of about 63 cents a perch. About 1000 perches were required for surfacing the portion of the road-bed which had been disturbed by the new grading. The other parts of the road already had a hard surface. The road was graded for a width of 20 feet and surfaced for a width of 12 feet. No roller was available to roll the road.

A picture of the abandoned part of this road is shown in Plate XVIII, Fig. 2. In the background on the right the fill of the newly located road can be seen. The cut in the old road opposite the fill in the new shows how the wear and wash of the road-bed and the ordinary methods of maintenance have increased the steepness of the hill.

Hollofield Road.

The section of the Old Frederick road near Hollofield station, on the Baltimore and Ohio railroad, descends to the level of the bridge crossing the Patapsco river by a series of steep grades, extending over a distance of three-fourths of a mile. It is the direct route to Baltimore for the people of a large section of the county and is the only road to Baltimore from Howard county with the exception of toll roads. The hill near Hollofield is one of the longest and steepest to be found anywhere on the road. The County Commissioners of Howard county wished to improve the grades on this section and appointed examiners to view the road, and requested the Highway Division to make the surveys and plans necessary for estimating the cost of reducing the grades.

The surveys were made and plans and profiles drawn. After a careful study of the road and its immediate vicinity, it seems advisable to relocate part of the road. By this means it is possible to reduce the present heavy grades of 10 and 13 per cent to 6 and 7 per cent. No work has yet been undertaken as the plans and profiles have just been completed.

Rockburn Branch Road (Projected).

The Highway Division was called upon by property owners in the neighborhood to make a preliminary examination of the valley of Rockburn Branch, near Relay Station on the Baltimore and Ohio railroad, with a view of building a road there to avoid the steep grades of the Lawyers Hill road, and to take advantage of the new iron bridge which has since been built across the Patapsco river near where the projected road would have reached the river side. It was found that the road could be built for a distance of something over two miles, without heavy grades, for about $4000, exclusive of surfacing. Nothing has yet been done.

PRINCE GEORGE'S COUNTY.

New Road Law.

The interest in the improvement of the roads resulted in the passage of a new road law for Prince George's county by the last General Assembly.[1] According to this law the roads and bridges are put under the general supervision and care of three County Road Commissioners who are elected by the people at the regular biennial elections and serve for two years. They purchase and distribute all necessary machines, tools, implements, and materials, the titles to which and also to all the roads and bridges in the county are vested in them. They must "provide each election district with one road-machine of an improved pattern." They receive $5 per diem when in the discharge of their duties, but no larger sum than $200 per year. The County Commissioners are required to divide the county into road-districts, no one of which is to be larger than an election district. A board of three District Road Trustees are appointed for each district by the County Board of Road Commissioners and they serve without pay except under special conditions; they have the immediate care of all small repairs and improvements and the maintenance of roads and bridges. When the repairs of a bridge exceed the sum of $200 the work must be let by contract by the Road Commissioners. The road-tax is not to be less than twenty cents in the one hundred

[1] Laws of Maryland, 1900; chap. 346, sect. 188.

dollars, three-quarters of which is to be distributed to the various districts for annual repairs, the other quarter is for incorporated towns and the expenses of the Road Commissioners. In addition to this, all money received from the liquor license is to be turned over to the Board of County Road Commissioners to be used "in the construction of permanent highways, beginning at the line of the District of Columbia, and at the end of some highway therein, and building out into the county upon existing public roads, continuing the same from year to year as funds may be available. Said work shall be done under the direction of the Geological Survey Commission Division of Highways of the State of Maryland, if the same be in existence."

All wagons with a capacity of 2000 pounds or more to be used in Prince George's county, which are bought or built after the passage of the law, are required to have tires at least four inches wide or pay a special license of $2 a year, which sum shall be used in the repairs of the roads.

The Board of Road Commissioners are "instructed to avail themselves of the advice and assistance of the Geological Survey Commission, Division of Highways of the State of Maryland, in the building of roads and bridges and the repairs thereof."

The new law has done much to improve the roads. The road-machines have been used to advantage, especially in the northern part of the county, where all the roads of Laurel, Vansville, Hyattsville, Bladensburg and Bowie districts have been shaped-up at a cost of $15 per mile. Excellent work has also been done with the machines in Marlboro, Melwood, Kent, and Queen Anne districts, but the machines have not so far been used very much in the southern parts of the county. About five miles of road have been graveled in Laurel, three in Vansville, seven in Hyattsville, and six in Bladensburg districts, including the roads leading from the District of Columbia, which are being permanently improved with the proceeds of the liquor license.

There has been no general election since the passage of the act until November, 1901, and therefore (as provided by the law) the Road Commissioners serving up to that time were appointed by the County Commissioners.

With the exception of the Queen Anne road, the Highway Division has not been called upon for assistance in the repairs of roads and bridges made with the general levy, but has been asked for specific plans for the improvement of the roads made with the proceeds of the liquor tax. The sum realized from this tax amounts to nearly $6000 a year.

The Board of Road Commissioners met and organized in the summer of 1900 and took up the question of the improvements of the roads leading out of the District of Columbia with the liquor tax. They decided to confine the money for the first year to not more than three roads, beginning with the Baltimore-Washington and the T B roads, and to apply some of the money later in the year to a third road if it should prove advisable. This met the approval of the Highway Division.

The interpretation of the law by the Highway Division was that a few roads of the county connecting with roads in the District of Columbia should be selected and the money of the liquor tax concentrated on them with the view of producing thoroughly good highways, and that these roads should continue to be improved from year to year until they should have been improved for their whole length within the county, or at least so far as they are important roads. It is undoubtedly to the advantage of the county as a whole to improve its most important roads first, rather than to improve all its roads at an equal but slow rate; and one long stretch of good road is more beneficial than the same distance of improved roadway divided up among many roads.

The Board requested the Highway Division to make surveys and estimates of the cost of construction of the two roads selected. This was done and plans and specifications for the work were prepared, together with an estimate of the cost; and work on these two roads was begun.

Legal Complications.

But the plans of the Road Commissioners met with opposition from a number of people in the county. It was thought by them that the Commissioners should distribute the liquor tax equally upon all the

roads leading into the county from the District of Columbia, and before the work proceeded very far they applied to the Courts for an injunction to restrain the Commissioners from expending more money on the two roads selected until an equal amount had been applied to the other thirteen roads. A preliminary injunction was granted early in the fall of 1900, and it was made permanent on November 13, 1900. It was not until May, 1901, that this decree was reversed by the Court of Appeals. The following is an extract from the opinion of the Court as handed down in this case: "Sec. 288, which has been heretofore quoted, is mandatory in two respects, and in two only; first, that the fund referred to shall be used only for the construction of permanent highways, and for such only as connect at the district line with some highway therein; and second, that the execution of the work shall be under the direction of the Geological Survey Commission, Division of Highways of the State of Maryland, if there be such Commission in existence; as to all else, the discretion of the Road Commissioners indicated throughout the Act, is unrestricted, either by express words or by implication. The language of the Act is not, 'beginning on the line of the District of Columbia at the end of *each* highway therein,' but, 'at the end of *some* highway therein.' To construe this Act as if it read, 'Beginning on each and every highway leading out of the District of Columbia, with a view to continuing such construction with equal proportional expenditure upon each and every of said highways,' as claimed by the appellees, would not only be a bald reconstruction of the Act, but would operate to reduce its beneficial results to the minimum. At each divergence of the highways after leaving the district line, no matter how numerous or how unimportant these diverging roads, a new subdivision of the fund would be required, without perceptible benefit to the citizens of any portion of the county. Such a result would inevitably follow such a construction of the Act, and we cannot attribute such purpose to the lawmaking body, in any view of the language it has used; nor do we hesitate to hold that the Road Commissioners have clear discretion to select the highways for permanent improvement under the terms of this Act. The character of their office, and the nature of

their duties, require that they should be vested with the discretion given them in the general supervision and control of the public roads, and the purposes for which they are directed to use this special fund are declared in terms which are inconsistent with the purpose to take away or restrict this discretion in the selection of highways embraced in the class designated for improvement. If they should be required to apportion this fund as claimed by the appellees, it would every year be frittered away without attaining any of the beneficial results contemplated by the Act."

At a meeting in June, 1901, the Road Commissioners decided to begin the improvement on the Riggs road, Central avenue, the Sheriff road, the Suitland road, and the Oxon Hill road, in addition to continuing the work on the Baltimore-Washington and T B roads, the amount to be expended on these new roads to be about $500 each. This did not seem a wise plan to the Highway Division, and recommendations were made to the Commissioners that they should pursue their policy of the previous year and confine the work to two or three of the principal roads. Recommendations were also made that all work be done by contract. After considering the matter, the Commissioners finally decided to begin work on the roads above named and requested that surveys and estimates for the construction be made, which the Highway Division has done.

Baltimore-Washington Road.

This road, which was once a toll-road, is probably more travelled than any other road in Prince George's county, and through neglect had gotten into a very bad condition. In dry weather it was covered with a deep layer of loose sand and dust which was changed into mud when the weather was wet. A little east of Hyattsville some graveling had been done about three years ago, but unfortunately without removing the heavy grades which at one point are as high as 9 per cent. There are several steep hills which materially increase the labor of hauling. The portion of the road surveyed by the Highway Division may be conveniently divided into three sections: the first from the District line to Bladensburg, a distance of about one mile;

the second within the limits of Hyattsville, a distance of about one-third of a mile; and the third a little less than one and a quarter miles east of Hyattsville, making the total distance surveyed two and one-half miles.

The recommendation of the Highway Division was to reduce the grades on the hills and to surface the road with gravel for a width of 15 feet. The plans and profiles showed just where the cuts and fills were to be made and the amount. No survey was made within the limits of Bladensburg. In Hyattsville there is a steep grade of 7½ per cent, which could be reduced to 4 per cent to great advantage; this part of the road does not come under the jurisdiction of the Road Commissioners, but they tried to induce the people of Hyattsville to make this improvement, offering to meet one-half the expense. The grade could have been cut down for $125 and the disturbed surface gravelled to a width of 15 feet for $160, but the town would not pay one-half this amount.

The specifications for the Baltimore-Washington road furnished by the Highway Division are given in full further on.[1] They cover the specifications for the other roads built with the liquor license fund. They call for the rolling of the road-bed, the surfacing with gravel, which is also to be rolled, and give other details regarding the construction. The Road Commissioners have not found it convenient to obtain a roller, and the roads have not been rolled.

Some work had already been done upon the first section of the road before the recommendations of the Highway Division were made. This consisted chiefly in cleaning out the ditches and gutters. Sod and other material, instead of being thrown away, had been thrown upon the road-bed, aggravating the already bad condition of the surface. The hills in this section have now been cut down and the surface graveled, making a very good road. Much difficulty was experienced in obtaining good gravel in the neighborhood; it had to be hauled a long distance and cost 10 cents per cubic yard in the pit. In the third section nearly a mile has been graveled, about 800 feet of this is within the limits of Hyattsville and about a quarter of

[1] Page 176.

a mile is on a part of the road beyond the survey of the Highway Division. A hill having a grade as steep as 9 per cent has not been cut down but work has been begun reducing a hill further on which lies outside of the limits of the survey and of the recommendations of the Highway Division. The work on this road has been done by day-labor under the supervision of Mr. Blundon, President of the Board of Road Commissioners.

T B Road.

The road leading from Anacostia through Silver Hill, known as the T B road, is the most important road in the southern section of Prince George's county, being perhaps the second most travelled in the county. Before the present improvement the road was in extremely bad condition, especially on the hills through the clay soil where the mud was very deep in wet weather, almost precluding any heavy hauling. The first hill encountered, about one-quarter of a mile from the District of Columbia, had grades of about 7 per cent for 400 feet. One-half mile beyond there is another hill 600 feet long with 8 to 10 per cent grades. There are steep grades of 9 to 13 per cent extending for a quarter of a mile on each side of Hensons Branch, two and three-fourths miles from the District line. At a point about three-fourths of a mile from the District line much trouble was caused by water under the road, and an underground drain was recommended to remedy this difficulty. The drain-pipe was laid before the road had been brought to the proper grade and had to be taken up and relaid. The work connected with this drain was very badly done.

The surveys were made for a distance of three and three-fourths miles, and it was recommended to reduce the first two hills to grades of 5 and 6 per cent, as shown on the plans and profiles prepared, and to cover the surface with gravel for a width of fifteen feet.

To reduce the grades on the slope north of Hensons Branch would require the excavation of 7000 cubic yards of material; the work has not yet extended so far.

The first two hills have been cut down and the road surfaced with gravel from the District line to a point near Silver Hill, a distance of

a little over one mile and a quarter. Excellent gravel was found in the hills where cuts were made so that but little had to be bought. Some of the gravel compacts very readily but contains a little too much clay, making it somewhat sticky in wet weather. To remedy this a surfacing of sandy gravel, which was found close by the road, was spread over the other gravel with excellent results. The gravel, however, was not spread properly, being dumped on the road in piles, which produced an uneven road-surface. If it had not been for this method of spreading the road would have been much better.

The work was done by day labor under the immediate supervision of Mr. Pyles, one of the Road Commissioners. The laborers were paid one dollar a day; two-horse team and driver, two dollars and a half; plough team of four horses and two men, six dollars, and about one hundred dollars were spent for gravel at the rate of five cents a cubic yard for gravel in the bank. The remainder was taken from cuts within the line of the road itself.

Oxon Hill Road.

This is a much-travelled road from the lower part of Prince George's county to Washington, entering the District of Columbia at a point near Congress Heights and connecting with the Livingston road. This is the road usually taken when travelling between Washington and the Government station at Indian Head on the Potomac. With the exception of a short piece of road near the District of Columbia, where the grade is 9 per cent, there are no heavy grades until the hill near Rosecroft Postoffice is reached. Here there are grades of 8 and 9 per cent extending for about 500 feet.

The surface of the road was extremely bad. It had been worn into ruts and holes, in which water stood in wet weather, and in many places the road was lower in the middle than at the sides. At one point, where the road crosses a small stream, there was no bridge. The recommendations of the Highway Division for the improvement of this road called for the reduction of the grades on the hill near the District of Columbia to 5 per cent, and those on the hill near Rosecroft Postoffice to 6 per cent, and the surfacing of the road with the best gravel in the vicinity. The plans and profiles furnished by the

Highway Division covered only those parts of the road on which a change in the grade had been recommended.

The road has been surfaced for about one mile from the District of Columbia, near which the gravel has been put on for a width of 16 to 18 feet. Further from the District the gravel is only 12 feet wide. Near the District where the gravel from stream-beds has been used the road seems fairly smooth, but the section where bank gravel has been used has not worn so well, as the gravel contains too much clay.

No grading has been done near the District of Columbia, although it has been graveled. The work has not extended as far as the Rosecroft hill. An iron bridge, 17 feet long and 15 feet roadway with stone abutments, has been erected over the small creek which was previously forded.

The work on this road was done by day-labor under the immediate supervision of the Road Trustee in whose district the road lies. Road Commissioner Pyles had general direction of the work. The prices paid for labor were the same as those paid for the T B and Suitland roads.

Suitland Road.

This road extends from the District of Columbia line to the Washington and Marlboro turnpike, a distance of three miles. There are no grades of any importance on the road with the exception of a hill about one-half mile from the District line, where the grades run from 6 to 7 per cent for about 500 feet. The road had been graveled but had worn to a very irregular surface. Depressions in the surface held water in wet weather and the road was then muddy. The Highway Division recommended the reduction of these grades to 5 and 6 per cent, and the surfacing of the road with gravel.

The work actually done on the road consists of surfacing with gravel beginning at a point about a mile from the District line and extending to within a few hundred yards of the eastern end of the road. The portion near the District line has not been graveled and the grade on the hill has not been reduced. The work was begun the latter part of August, 1901. The gravel for the surfacing was

obtained from gravel banks in the vicinity of the road. The quality varies considerably, some of the gravel containing much more sand than other portions. The gravel was dumped upon the road in piles and not carefully spread, as is shown by the numerous hollows in the road which have formed between the piles where the gravel has not become so well compacted. This was specially noticeable in gravel containing the most clay. The width of road graveled varies between 10 and 15 feet, the wider portion being the part nearest the District of Columbia. The work was done by day-labor under the immediate supervision of Mr. Cassard, President of the Board of County Commissioners, who gave his time gratuitously. The laborers were paid $1.00 per day; two-horse team and driver, $2.50; plough team of four horses and two men, $6.00. Some of the gravel used upon the road was purchased at five cents per cubic yard in the bank, and some of it was contributed by the people living along the road.

Riggs Road.

The Riggs road enters the western corner of Prince George's county and runs northeasterly through one of the most beautiful sections of the county. For a distance of about one mile it is well travelled but beyond this the road forks and the travel on either branch is much lighter. There are two hills with steep grades within the distance surveyed, something less than one and one-fourth miles. The first hill, one-half mile from the District line, has grades as high as 7 per cent for a distance of about 400 feet. The second, three-fourths of a mile from the District line, is about 1100 feet long, and the grades on it run as high as 10 per cent. With regard to the surface, it was an ordinary dirt road.

The plans for the improvement of this road call for the reduction of the grades on these hills, the first to 5 per cent and the second to 5½ per cent. The road was to be graveled for a width of 15 feet, the whole roadway being 20 feet wide. The work is now in progress and is being done by contract. The price for excavation is 20 cents per cubic yard for a haul not exceeding 300 feet, with an increase of one cent per cubic yard for every addition of 100 feet in the length of

the haul. The gravel costs 49 cents per cubic yard spread on the road.

Central Avenue.

This is the direct road from Washington to Annapolis and is one of the most important roads leading from the District of Columbia into Prince George's county. Near the District it is hilly and the surface is in a bad condition. In places on the hills the road has been washed and in the hollows it is sandy. The survey of the Highway Division extended a little more than two miles. The plans call for the reduction of the grades and surfacing with the best gravel obtainable in the vicinity. One hill to be graded crosses the District line, and it is hoped the District Commissioners will cooperate with the County Road Commissioners in doing this part of the work, which has therefore been postponed for the present. The Road Commissioners advertised for bids for the improvement of this road, but only one was received, namely, 30 cents per cubic yard for excavation and 50 cents per cubic yard for gravel spread on the road. The Commissioners considered these prices too high and have undertaken the work by day-labor. The work has not yet progressed very far.

Sheriff Road.

This road runs eastward about one and a half miles north of Central avenue. It is extremely hilly and the cost of reducing the hills to reasonable grades will be very large. It has been surveyed for about a mile from the District line. No work towards its permanent improvement has been begun, but a bad washout some distance beyond the part surveyed has been repaired.

The following account, furnished by the Board of Road Commissioners, shows the sums spent on the various roads improved by the liquor license fund, from the organization of the Board in the summer of 1900 to October 15, 1901:

Total amount received		$9,163.78
Total amount expended T B road	$3,665.74	
Total amount expended Baltimore and Washington Turnpike	2,742.73	
Total amount expended Suitland road	553.45	
Total amount expended Oxon Hill road	322.33	
Total amount expended Central avenue	489.25	
Total amount expended Riggs road	150.00	
Total amount expended Sheriff road	224.45	
Total amount in Counsel's fees	403.30	
	$8,551.25	
Amount in Bank	612.53	$9,163.78

Queen Anne Road.

This road runs eastward from Upper Marlboro, at first over a sandy stretch, and then up a steep hill. The Patuxent Planters' Club requested the Highway Division to survey this part of the road and give advice regarding the best method of improving it. The survey was made but the Road Trustees carried out some minor repairs before the survey was finished, and no improvement of importance has been made.

Summary of Road Expenditures in the Counties from Reports of the Boards of County Commissioners.

The following table showing the amounts spent in 1899, 1900, and 1901 upon the public roads in the counties has been compiled from information furnished by the Boards of County Commissioners, or Road Commissioners, in the various counties, in answer to a circular sent from this office. Owing to better systems of keeping the accounts, some of the counties have been able to make a more detailed report than others. The circular asked for an account of all new roads opened, of special work done on the roads, and of new machinery purchased in the past three years. So far as this information has been furnished, it is summarized in the paragraphs following the table of expenditures.

TABLE OF ROAD EXPENDITURES 1899–1901.

County.		Total amount spent on Roads and Bridges.	Amount spent for Bridges.	Amount spent for New Roads.	Amount spent for Permanent Improvement as stone, shell or gravel.	Amount spent for Repairs.
Allegany,	1899	$42,054.63	$6,081.87	$1,500.00	$5,000.00	$29,472.76
	1900	64,892.59	9,041.39	2,400.00	25,000.00	28,451.20
	1901	65,185.27	4,800.00	6,700.00	25,000.00	28,685.27
Anne Arundel,	1899	49,793.84	8,654.93	*	*	41,138.91
	1900	45,687.59	4,985.00	*	*	40,702.59
	1901	†	†		†	*
Baltimore,	1899	170,495.70	*	*	*	*
	1900	156,290.87	*	*	*	*
	1901	149,227.81	§	§	§	*
Calvert,	1899	4,377.70	377.70	....	....	4,000.00
	1900	5,825.00	975.00	30.00	525.00	4,295.00
	1901	5,295.00	425.00	....	300.00	4,570.00
Caroline,	1899	10,692.20	*	*	*	*
	1900	9,511.34	*	*	*	*
	1901	8,577.97	*	*	*	*
Carroll,	1899	21,574.93	3,055.60	277.10	....	18,242.23
	1900	20,002.68	2,668.31	192.55	....	17,141.82
	1901	20,087.32	1,436.16	54.00	....	18,597.16
Cecil,	1899	28,713.57	10,598.10	*	*	18,115.47
	1900	34,748.76	2,433.32	*	*	32,315.44
	1901	22,942.46	199.50	*	*	22,742.96
Charles,	1899	11,500.00	1,100.00	2,500.00	*	7,900.00
	1900	10,000.00	....	1,500.00	*	8,500.00
	1901	8,000.00	900.00	....	*	7,100.00

*Not reported. †Not reported, fiscal year ends in June. § See Report of Roads Engineer.

TABLE OF ROAD EXPENDITURES 1899-1901.—Continued.

County.		Total amount spent on Roads and Bridges.	Amount spent for Bridges.	Amount spent for New Roads.	Amount spent for Permanent Improvement as stone, shell or gravel.	Amount spent for Repairs.
Dorchester,	1899	$16,000.00	$2,678.46	*	$5,000.00§	$8,321.54
	1900	15,113.15	2,119.98	*	5,000.00§	7,993.22
	1901	10,000.00†	*	*	*	*
Frederick,	1899	33,512.17	4,166.05	$4,518.82	1,500.00‡	23,327.30
	1900	40,850.36	13,957.25	2,254.44	2,000.00‡	23,638.67
	1901	37,200.00‡	8,000.00‡	1,200.00‡	1,500.00‡	26,500.00‡
Garrett,	1899	12,280.59	1,493.59	104.00	....	10,683.00
	1900	14,332.47	3,482.72	49.75	....	10,790.00
	1901	12,534.73	1,000.00	278.00	....	11,256.73
Harford,	1899	25,000.00	*	*	5,000.00	20,000.00
	1900	26,000.00	*	*	5,000.00	21,000.00
	1901	36,500.00‖	*	*	18,000.00‖	18,500.00
Howard,	1899	21,445.16	5,250.80	293.00	7,973.05	7,928.31
	1900	24,615.05	5,145.15	1,092.20	11,367.73	7,009.97
	1901	22,517.63	6,982.00	587.00	8,222.15	6,726.48
Kent,	1899	30,211.32	1,938.59	785.45	840.06	26,647.22
	1900	17,659.61	3,798.19	1,460.69	76.41	12,324.32
	1901	18,756.60	4,425.04	669.37	946.86	12,715.33
Montgomery,	1899	25,472.21	5,987.21	1,435.00	6,700.00	11,350.00
	1900	25,121.16	4,338.66	2,332.50	6,700.00	11,750.00
	1901	26,236.71	6,976.71	760.00	6,800.00	11,700.00
Prince George's,	1899	19,000.00¶	*	*	*	*
	1900	23,285.00	5,400.00	*	4,385.00	13,500.00
	1901	30,021.00	7,100.00	*	5,721.00	17,200.00

*Not reported. †Amount levied, fiscal year ends in June. ‡Estimated by County officials. §Estimated from quantity of shells used as reported by County officials. ‖Includes $13,000.00 being spent on Churchville road, $10,000.00 of which is paid from the Woolsey bequests. ¶Not reported by County Commissioners. Estimated from expenditures for 10 years, preceding 1899.

TABLE OF ROAD EXPENDITURES 1899–1901.—Continued.

County.		Total amount spent on Roads and Bridges.	Amount spent for Bridges.	Amount spent for New Roads.	Amount spent for Permanent Improvement as stone, shell or gravel.	Amount spent for Repairs.
Queen Anne's,	1899	$13,301.03	$4,053.59	$386.95	*	$8,860.49
	1900	11,364.62	3,741.76	436.87	....	7,186.49
	1901	12,000.00†	4,000.00†	300.00†	....	7,700.00
St. Mary's,	1899	5,250.00‡	*	*	*	*
	1900	5,250.00‡	*	*	*	*
	1901	5,250.00‡	*	*	*	*
Somerset,	1899	11,071.04	2,900.34	....	$3,474.67	4,696.03
	1900	10,301.05	2,160.00	....	2,059.90	6,081.15
	1901	10,430.21	1,880.91	....	1,837.25	6,712.05
Talbot,	1899	16,855.03	6,369.45	29.50	*	10,456.08
	1900	10,058.60	2,180.65	290.34	*	7,587.61
	1901	§	§	§	§	§
Washington,	1899	18,879.45	6,332.67	469.00	....	12,077.78
	1900	18,433.32	4,802.18	407.00	....	13,224.14
	1901	15,263.41	1,845.57	187.00	100.00	13,130.84
Wicomico,	1899		*	*	*	*
	1900	6,126.00	*	*	*	*
	1901		*	*	*	*
Worcester,	1899	3,500.00	*	....	....	*
	1900	6,500.00	*	....	....	*
	1901	7,000.00	*	300.00	....	*
State,	1899	593,022.57	**	**	**	**
	1900	597,875.22	**	**	**	**
	1901	581,100.00¶	**	**	**	**

*Not reported. †Estimated by County officials. ‡Not reported by County Commissioners. Estimated from expenditures for 10 years, preceding 1899. §Not reported, fiscal year ends in June. ** Not Estimated. ¶ Estimated.

ALLEGANY COUNTY.—During 1899, 1900, and 1901 five and one-half miles of new roads were opened. None of the county roads have secured special appropriations for improvements beyond the usual amount expended by the Road Supervisors. In the past three years the county has purchased additional road-machinery, consisting of a rock-crusher, two engines and boilers for operating the rock-crusher, and two road-machines, at a total cost of $2145.00.

ANNE ARUNDEL COUNTY.—In 1900 $4000 were spent for the special improvement of the South River road, an account of which is found on page 132. No information as to amount of new roads opened and new road-machinery purchased was returned by the County Commissioners' Office.

BALTIMORE COUNTY.—During 1901 there were $475 contributed in money by private subscription for use on county roads. The county has purchased a second-hand stone-crusher and engine and has installed a crusher at Weber's quarry near Ellicott City. An account of the new road-law and the work of the Highway Division is found on pages 137-141. The report of the County Roads Engineer is given on pages 179-201.

CALVERT COUNTY.—The special license-money received from Chesapeake Beach, amounting to $570 a year, has been used on the roads of the county in 1900 and 1901. No road-machinery has been purchased in the past three years. But very little money is expended on what could be called, in any way, permanent improvements.

CAROLINE COUNTY.—The county has made no expenditures for new road-machinery, nor have any new roads been opened.

CARROLL COUNTY.—No new roads or new road-machinery are reported.

CECIL COUNTY.—No new roads or new road-machinery are reported.

CHARLES COUNTY.—Four and one-half miles of new roads were opened in 1899. Road-machines are not used.

DORCHESTER COUNTY.—About 250,000 bushels of shells are used each year upon the roads. The county purchased a new road-machine in 1901. During the past three years about $500 have been spent upon the public roads from private subscriptions.

FREDERICK COUNTY.—Twenty-two miles of new roads have been opened. A small amount has been expended on grading hills. Several hundred dollars have been spent on repairs to the road-machinery owned by the county; and nine new road-machines have been purchased at a cost of $1475.

GARRETT COUNTY.—In addition to the regular levy, $1658 were spent in 1899, $1455 in 1900, and $1921.73 in 1901. Sixteen miles of new roads have been opened during the past three years. The county has purchased a road-machine costing $235, and has spent $60 on repairs of old machines.

HARFORD COUNTY.—Nine and one-quarter miles of new roads have been opened. In 1901 a steam road-roller was purchased at a cost of $2675. Three scrapers have also been purchased at a cost of $480. A report of the special work done with funds from the Woolsey Bequests is found on pages 141-145.

HOWARD COUNTY.—Special appropriations of $600 in 1900, and $500 in 1901, were made for road-work. In the past three years two and three-quarters miles of new road have been opened. One second-hand stone-crusher costing $636, and two road-machines costing $320, have been added to the road-machinery of the county. The County Commissioners have given much attention to the permanent improvement of many county roads. Few counties have done as much permanent work as Howard county in proportion to their respective road funds. An account of the work in which the Highway Division has given aid is found on pages 146-148.

KENT COUNTY.—Four and one-quarter miles of new roads have been opened. No new road-machinery has been bought, but $331.04 have been spent on repairs to old machinery. In 1900 and 1901 the county spent $200 each year on the streets of Millington.

MONTGOMERY COUNTY.—About $32,000 were expended rebuilding the old Georgetown turnpike. Of this amount, $25,000 was raised by an issue of bonds. The work has been in progress since 1898. An account of the beginning of this work is found in the Highway Report for 1899, page 242.

PRINCE GEORGE'S COUNTY.—In 1901 the county purchased three

road-machines and four heavy road-ploughs. The Road Commissioners report that 17 new bridges have been built and 13 old iron bridges painted with asphalt paint, which is a great protection to them. A full account of the work done on the roads under the new road-law of 1900 is found on pages 148-159.

QUEEN ANNE'S COUNTY.—One and one-half miles of new roads have been opened. No new road-machinery has been purchased.

ST. MARY'S COUNTY.—No report or answer to numerous requests for information has been received from the County Commissioners' office.

SOMERSET COUNTY.—No new roads have been opened nor has any new road-machinery been purchased. A considerable amount is spent annually on shelling the roads. Special attention has been given to the construction of ditches alongside the roads to underdrain the road-bed. Small wooden drains are being replaced by tile drains.

TALBOT COUNTY.—Three miles of new roads were opened in 1900. No new road-machinery has been purchased.

WASHINGTON COUNTY.—Eleven and three-quarters miles of new roads have been opened. The county has purchased no new road-machinery.

WICOMICO COUNTY.—The only report received from the County Commissioners' office in answer to numerous requests for information was "Board expenditures $6126.00."

WORCESTER COUNTY.—Three miles of new roads were opened in 1901. No new road-machinery has been purchased.

CONTRACT AND SPECIFICATIONS FOR THE BELAIR-CHURCHVILLE ROAD.

ADVERTISEMENT.

OFFICE OF COUNTY COMMISSIONERS OF HARFORD COUNTY.

Bel Air, Md., 1901.

SEALED PROPOSALS, addressed to the County Commissioners of Harford County will be received up to 12 o'clock noon ——————————, 1901, when they will be publicly opened and read, for the improvement of the County road between Bel Air and Churchville in Harford County.

The work has been divided into four sections as described and shown in the plans and specifications to be seen at the office of the County Commissioners at Bel Air, and will be known as Sections 1, 2, 3, and 4, respectively.

Separate bids must be made for each section desired, but a single bid may be submitted for the whole work if accompanied by bids for each section.

Bids for doing the work must be done in accordance with the plans and specifications approved by the County Commissioners and on file at their office.

The County Commissioners of Harford County expressly reserve the right to reject any or all bids. Before the contract is awarded the successful bidder or bidders will be required to furnish a bond of $200.00 for faithful performance of the work in accordance with the plans and specifications aforesaid.

BY ORDER OF COUNTY COMMISSIONERS OF HARFORD COUNTY.

PROPOSAL.

To the COUNTY COMMISSIONERS OF HARFORD COUNTY:

For the improvement as hereinafter specified, of the section of County road between Bel Air and Churchville, located in Harford County, State of Maryland.

Made by (name) Chas. A. Hook & Son,
(Address) 17 E. Fayette St., Balto. City,
or 2nd Nat. Bank, Bel Air, Harford County.

The undersigned hereby declare that they have carefully examined the annexed form of contract and specifications and the drawings forming a part of the same and have to their satisfaction examined the road upon which improvement is proposed and agree to furnish all tools, machinery and other means of construction (with the exception of a steam-roller, provision for which is hereinafter made) that may be necessary, and to do all the work and furnish all material as called for and in the manner provided by annexed contract, specifications and drawings thereto and requirements under them of the Engineer, for the following prices, to wit:

For EXCAVATION of all descriptions except ledge, including all grubbing, clearing and incidental work,....forty cts. (40c.) per cu. yd.

For LEDGE EXCAVATION including all incidental work, One Dollar ....($1.)............per cu. yd.

For EXCAVATION for "borrowed material" when outside the line of the road, including all incidental work not exceeding one-half mile haul, Forty. . . ..(40c)............per cu. yd.

For SHAPING ROAD-BED, including all clearing, grubbing, forming of gutters, and all incidental work, not requiring a change in the present grade of the road-bed of over 8 inches, Four cents (.04)................per sq. yd.

For LOOSENING AND SHAPING PRESENT STONE SURFACE so as to form a proper cross-section, not including additional broken stone that may be required, Twenty-five (25c)..............................per sq. yd.

For TELFORD FOUNDATION in place, including all materials and incidental work, twenty-five cts., (25c)............................per sq. yd.

For CRUSHED STONE in place, including all materials, rolling and incidental work as provided for in the specifications, measured in the carts:

From Quarry A. on Bruns' Estate,
For 1st and 2nd Sections...........................$1.40 per cu. yd.
For 3rd and 4th Sections........................... 1.40 per cu. yd.
From Quarry B. on Pocock's Estate,
For 1st and 2nd Sections........................... 1.40 per cu. yd.
For 3rd and 4th Sections........................... 1.40 per cu. yd.
From Quarry C. on Livesey's Estate.
For 1st and 2nd Sections........................... 1.40 per cu. yd.
For 3rd and 4th Sections........................... 1.40 per cu. yd.

For ALL VITRIFIED DRAIN PIPE, including all materials, excavations (except ledge) and incidental work,

24 inch ....per ft.
18 inch, $1...per ft.
12 inch ....per ft.
6 inch, 30c...per ft.

For IRON WATER PIPE, including all materials, excavation (except ledge) and incidental work,

12 inch, $1.73..per ft.
18 inch, 3.00...per ft.
24 inch, 3.00...per ft.

For CEMENT RUBBLE MASONRY, including all materials and incidental work, except excavation, $3.50 ....per cu. yd.

For DRY RUBBLE MASONRY, including all materials and incidental work, except excavation, $2.50 ....per cu. yd.

For EXTRA WORK ordered in writing by the County Commissioners, including use of all tools:

For materials furnished by contractor, actual cost as shown by paid vouchers.

For laborers ....15 cents ....per hour.
For single team and driver, 10 hour day, at county rates plus 10 per cent.
For double team and driver, 10 hour day, at county rates plus 10 per cent.

Accompanying this proposal is a certified check for $200.00 drawn on ...., payable to the County Commissioners of Harford County, which shall become the property of said Commissioners should this proposal be accepted by said Commissioners and

the undersigned fail to execute the contract with said Commissioners, otherwise the check will be returned to the undersigned.

(Signed) Name, Chas. A. Hook & Son,
Adress, 17 E. Fayette St., Baltimore.

Date, 8....19....1901. (Give name and addresses of all persons who are interested in this contract as bidders.)

CONTRACT.

STATE OF MARYLAND.

COUNTY COMMISSIONERS OF HARFORD COUNTY.

For improving all the sections of the county road between Bel Air and Churchville in Harford County, made and concluded on the 19th day of August, 1901, between the County Commissioners of Harford County, party of the first part, and Charles A. Hook & Charles A. Hook, Jr., trading as Charles A. Hook and Son, parties of the second part. The distance between Bel Air and Churchville has been divided into four sections, viz.:

1st section from Main Street, Bel Air, to Bynum's Run Bridge, as shown on the plans from Station 0 to Station 55.

2nd section extends from Bynum's Run Bridge to a point near Fountain Green P. O., as shown on the plans from Station 55 to Station 108.

3rd section extends from Fountain Green P. O. to a point near Schuck's corner, as shown on the plans from Station 108 to Station 189.

4th section extends from Schuck's corner to the cross-roads at Churchville, as shown on the plan from Station 189 to Station 289.

WITNESSETH: That in consideration of the sums hereinafter mentioned to be paid by the party of the first part, and penalty expressed in the bond of even date with these presents and annexed hereto, the said party of the second part agrees with the said party of the first part, at his own proper cost and expense, to do all work and furnish all materials necessary to improve the portions of the county road between Bel Air and Churchville in Harford county, as shown on the plans and described above as all the sections thereof, in accordance with and as described in the specifications herein contained and in full compliance with the terms of this agreement.

IN WITNESS WHEREOF the parties hereto have set their hands the date herein mentioned.

(Signed) W. A. DURHAM,
JOSEPH E. SPENCER,
B. F. HANWAY,
County Commissioners for Harford County.
CHAS. A. HOOK & SON, Contractors.

SPECIFICATIONS.

For improving the County road between Bel Air and Churchville in Harford County, beginning at a point near Bel Air and extending to a point near Churchville.

Length.

Approximate length of road to be improved is 5.47 miles.

Work to be Done.

The contractor is to furnish all tools, machinery, labor, and to do all the work in connection with the proposed improvement of said road (except as herein specified), including all grading, draining, and surfacing in accordance with these specifications and plans and requirements under them of the Engineer. Said plans are to be signed by the County Commissioners of Harford County and by the Highway Engineer of the Maryland Geological Survey, and form a part of these specifications. The contractor is to leave the road and immediate vicinity in a neat and presentable condition ready for use.

The County Commissioners will furnish free of cost to the contractor a steam-roller, including pay of a competent driver, cost of fuel, water, oil and waste, said driver to be under the orders of the contractor, who hereby agrees to assume all expense arising from injury or damage to said roller of whatever description and from any cause whatsoever while said roller is on the work or under his orders, and to return the roller in as good a condition as when received. The rolling is to be done as hereinafter specified.

The County Commissioners will also furnish to the contractors, free of any cost, quarry rights in the following quarries: Quarry A. on the Bruns' Estate, ¼ mile from the road, at a point near Bynum's Run Bridge. Quarry B., located on Mr. Pocock's Estate, at the side of the county road, about one mile distant from the Bel Air road. Quarry C., located on Mr. Livesey's Estate, about one mile from Bel Air road.

Bidders are requested to give prices for furnishing broken stone from each of the above quarries: first, for broken stone for the first and second sections of the work; second, for broken stone for the third and fourth sections; in each instance giving price from all of the above-named quarries. If but one price is given it will be assumed to cover all the sections of the work for which the proposal is made. In addition, bidders may submit prices for broken stone obtained from other quarries provided the rock is of a quality acceptable to the Highway Engineer of the Maryland Geological Survey. The kind and quality of broken stone to be used upon any particular portion of the road will be determined by the Engineer, and any directions which he may give in this particular are to be strictly followed.

Estimated Quantities.

The following quantities of the work to be done are approximate only and are intended principally to serve as a guide in figuring out the bids. These quantities may be subsequently increased or diminished as may be deemed necessary by the County Commissioners of Harford County as hereinafter provided in the specifications.

Excavations (other than ledge)	cu. yds.	2978
Excavation "borrowed material"	" "	...
Ledge Excavation	" "	200
Rubble Masonry laid dry	" "	....
Rubble Masonry laid in cement	" "	....
Brick Masonry	" "	....

Vitrified clay pipe.	Linear ft.	
6″	" "	300
18″	" "	135
12″	" "	....
24″	" "	....
Iron Pipe.		
24″	" "	....
18″	" "	30
12″	" "	174
Shaping road-bed	sq. yds.	20,028
Loosening and shaping present stone surface	" "	1580
Telford Foundation	" "	13,464
Crushed stone	cu. yds.	4593

Estimated Quantities by Sections.

		SECTIONS			
		1	2	3	4
Excavation (other than ledge)	cu. yds.	2123	443	133	279
Excavation "Borrowed Material"	" "	....	....	....	....
Ledge Excavation	" "	200	....	....	....
Rubble Masonry laid dry	" "	....	....	....	....
Rubble Masonry laid in cement	" "	....	....	....	....
Brick Masonry	" "	....	....	....	....
Vitrified clay pipe.					
6″	" "	....	300	....	....
18″	" "	75	60	....	....
24″	" "	....	....	....	....
Iron pipe.					
12″	" "	....	30	48	96
18″	" "	....	30	....	....
24″	" "	....	....	....	....
Shaping road-bed	sq. yds.	4506	7066	4524	3932
Loosening and shaping present stone surface	" "	....	....	....	1580
Telford Foundation	" "	....	7066	4524	1874
Crushed Stone	cu. yds.	1164	1335	854	1240

Earth Work.

The road-bed shall be graded for a width of 20 feet in conformity with the plans, profiles and cross-sections which accompany and are a part of these specifications.

All materials excavated within the lines of the work and used for filling are to be paid for as excavation only. Materials used for filling brought from outside the lines of the work are to be paid for as "borrowed."

Embankments are to be made in layers not exceeding 12 inches in thickness until the proper grade is reached.

All measurements for earthwork are to be made in excavation.

All surfaces and slopes are to be left smooth and neat.

Ledge Excavation.

Only boulders measuring over ½ cubic yard or ledge requiring blasting for its removal, shall be classed as ledge, nor will allowance be made for ledge excavation more than 6 inches below subgrade.

Dry Rubble Masonry.

It shall be composed of quarry stone free from structural defects and presenting good beds for material of this kind and of suitable sizes and shapes for the work, laid so as to give a bond of at least 6 inches and with sufficient headers to give well-bonded work, the larger stone to be used for foundation purposes.

Covering stone not to be less than 12 inches thick, laid with close joints, and ends overlapping side walls at least 12 inches.

Cement Rubble Masonry.

Cement masonry shall be used wherever directed by the Engineer and shall consist of sound stone with beds suitable for this class of work. The stone is to be laid in courses not less than 12 inches thick with alternate headers and stretchers.

The joints shall not be over 1 inch wide and well filled with cement mortar.

Cement mortar is to consist of one part American cement and two parts clean, sharp sand, or one part Portland cement and three parts clean, sharp sand. The cement is to be kept until used in tight barrels or bags thoroughly protected from all moisture.

No mortar is to be used that has stood over 45 minutes, or has taken an initial set, or has been re-tempered.

Pipe Culverts.

The trenches are to be excavated to the grade shown on the plan and profile, and as given by the Engineer, so as to insure a true alignment for the pipe.

Care must be taken that each section of the pipe has a firm bearing throughout its length.

All pipe must be sound and free from cracks and distortions.

No other allowance than the price per foot for laying pipe will be made for excavating the trench except where the contractor is directed to dig the trench more than 3 feet deep, allowance then being made for all material excavated beyond 3 feet.

Shaping Road-Bed.

In cuts and fills, unless specially directed, the road-bed is to be graded to a width of 20 feet, and is to be free from all spongy and vegetable matter, roots, and stumps. The road-bed prepared for the broken stone surface is to be twelve feet wide and brought to the grade and cross-section as shown on the plans and rolled with a steam-roller until firm and hard. All depressions that may appear during the rolling are to be filled with earth and rolled until an even surface is obtained.

Where no change from the present grade of those portions of the road not already surfaced with stone is shown on the profile, the road-bed is to be shaped to the proper cross-section and rolled to a firm smooth surface before the application of broken stone, the price for this work to be included in that for "shaping road-bed," and is to include all excavation and work that may be necessary for removing slight elevations and contiguous depressions, and also excavation for telford or macadam constructions which do not require a change in the present grade of the road-bed of over 8 inches. The width to be paid for in shaping the road-bed to be only that covered by the broken stone.

Loosening and Shaping Present Stone Surface.

Where deemed necessary by the Engineer, the surface of those portions of the road-bed now covered with broken stone is to be loosened and given the proper cross-section, this class of work to be paid for by the square yard. Should it be necessary after loosening the old road-bed to add more broken stone in order to form the proper cross-section, all extra stone so furnished will be paid for at the price agreed upon for the character of broken stone so used.

The price for loosening present stone surface is to be allowed only when the present grade remains unchanged, and is not to be allowed on those sections of the road where the old bed is entirely removed in order to reach the proper grade. In this last instance the only price allowed will be that for excavation.

Telford Construction.

Telford Foundation.

The telford foundation is to be used whenever directed by the Engineer. The road-bed is to be first shaped and rolled as already described and stipulated for. The stone for the foundation course shall be sound with sharp corners, with a depth of 5 to 8 inches, width 3 to 6 inches and length not exceeding 15 inches. They are to be laid lengthwise across the road with broad base down. Protruding corners shall be broken off and spaces filled with smaller pieces; the whole to be rolled until firm. Should any depressions show, they shall be filled with stone and rolled until firm. The interstices must not be filled with earth. The thickness of the telford foundation is to be 8 inches when finished. The price paid for telford foundation is to include all work and materials necessary to do the work as above described.

Surfacing of Telford Foundation.

Broken stone, varying in size from ¾ to 1½ inches (No. 2), is to be spread over the telford foundation so as to roll to a thickness of 4 inches, and shall consist of crushed trap rock unless otherwise directed by the Engineer. Broken stone is to be spread with shovels from piles alongside of the road or from a dumping-board, or it may be spread directly from wagons specially constructed for this purpose, but in no case shall the stone be dumped directly upon the foundation course, except that broken stone may be put directly on the road-bed from wagons if the pile of stone be continuous and in the center of the road.

After spreading, the broken stone is to be rolled until firm and thoroughly compacted.

Finishing Course.

A surfacing of screenings to consist either of trap rock screenings or other binding material, as the Engineer may direct, is to be applied in the same manner as specified for the finishing course for macadam construction.

Macadam Construction.

Macadam construction is to be used wherever directed by the Engineer or provided for in the plans.

First Course.

The first course is to consist of sound stone broken to sizes varying from 3 inches to 1½ inches (No. 1). The thickness of the first course after rolling is to be not less than 4 inches and shall be thicker than this where specially ordered by the Engineer. The broken stone is to be spread as already described for spreading the surfacing over a telford foundation.

After spreading, the stone is to be rolled until firm and thoroughly compacted and with a cross-section to conform to that shown by the drawings.

Second Course.

The second course shall consist of stones varying in size from 1½ to ¾ inches (No. 2), and shall be crushed trap rock unless otherwise ordered by the Engineer. The thickness of the second course is to be 2 inches after rolling, and the manner of spreading is to be the same as provided for the first course.

After spreading, it is to be rolled until the stones are firm and thoroughly compacted.

Third Course.

The third course shall consist of trap rock screenings varying in size from ¾ inch to dust. The screenings are to be spread dry sufficient to barely fill the interstices and should be then swept in, watered and rolled, after which from 1½ to 1 inch additional screenings are to be spread dry, watered and rolled until the surface becomes hard and smooth. In no case shall the screenings be rolled in dry. When specially directed by the Engineer, other binding materials than trap rock-screenings may be used, but should be applied in the manner above described. Screenings should be dumped and spread in the manner specified for broken stone.

Resurfacing Portions of the Present Road Covered with Stone.

After bringing the present surface to the proper cross-section, as directed in "Shaping the road-bed," it is to be covered with a layer of broken trap rock, varying in size from 1½ to ¾ inches, so as to roll to a thickness of not less than 3 inches, the broken stone to be applied before rolling the loosened stone of the old surface unless the process of shaping-up the old road-bed has necessitated a thickness of more than 4 inches of loosened stone, in which case it shall be first rolled before applying the top layer. The broken stone for the resurfacing is to be spread, rolled, and finished in the manner indicated for spreading the broken stone for macadam construction.

Rolling.

The rolling of the different courses of stone should begin at either edge of the road and work towards the middle. Any special directions as to the manner of rolling which may be given by the Engineer in order to secure the best results shall be strictly followed.

Extra Work.

Upon receipt of written orders signed by the County Commissioners, the contractor agrees to do such extra work and furnish such materials as may be necessary for the same. The contractor shall receive the actual cost of all materials so furnished, as shown by paid vouchers, and for such labor and teams as are necessary, the price as herein agreed upon.

General Clauses.

Plans, Profiles and Specifications.

The plans, profiles and specifications are hereby made a part of this contract and will be held to cover any and all work that could reasonably be inferred as needed for a complete and workmanlike job. And it is understood no advantage will be taken of discrepancies found in any drawing or specification. If any doubt or dispute arises in regard to interpretation of these specifications, plans, or contract, the same shall be referred to the Engineer, whose decision shall be final.

Changes in Plans.

The right is reserved to make such changes in the plans or specifications as may from time to time appear necessary or desirable, and such changes shall in no wise invalidate this contract. Should such changes be productive of increased cost to the contractor a fair and equitable sum therefor, to be agreed upon before such changed work shall have been begun, shall be added to the contract price, and in like manner deductions shall be made.

Contractor's Liability.

The contractor hereby assumes all risks and liabilities for accidents and damage that may accrue to persons or property during the prosecution of the work by reason of the negligence or carelessness of himself, his agents or his employees.

Sub-Letting Contract.

The contractor agrees to give his personal attention to this contract and not to sub-let the same, or any portion, without written consent of the Commissioners.

Instructions to Foreman.

The superintendents or foremen of any particular portion of the work shall receive and obey the instructions of the Engineer referring to that particular part of the work which he is in charge of, in case the contractor himself is not present.

Work Begun and Completed.

The work is to be begun within 10 days after the execution of this contract, to be diligently prosecuted to completion in such order as may be prescribed by the Commissioners.

The contractor hereby agrees to complete the work on or before May 1, 1902, which date may be postponed at the discretion of the Commissioners.

The County Commissioners hereby agree to close the road to travel section by section as the work progresses, but at no time will more than one section be closed unless the County Commissioners should so direct.

Laws and Ordinances.

The contractor and those under him shall conduct the work in such a manner as to fulfill all the requirements of State, County or Town laws and ordinances applying to the work in hand, and he shall take such necessary precaution as will guard against losses of life or accident.

Clearing Up.

The contractor is to leave the road in a neat and presentable condition, and to remove and clear up all rubbish and surplus material.

Disorderly Persons.

Should any person employed by the contractor appear incompetent or disorderly, he shall be immediately discharged upon request of the Engineer and shall not be employed again upon the work.

Definitions.

Where the word "Commissioners" is used in this contract it shall be understood to mean the Board of County Commissioners for Harford County, party of the first part to this contract, or their authorized representatives limited by the particular duties intrusted in him.

Whenever the word "Contractor" is used, it is understood to mean the person or persons who have entered into this contract as party or parties of the second part.

Whenever the word "Engineer" is used, it is understood to mean the Highway Engineer of the Maryland Geological Survey or his authorized representative.

Payments.

Payments will be made by the Commissioners to the contractor on work done under this contract as follows:

On monthly estimates furnished by the Engineer less ten per cent due on the said estimate; said ten per cent is to be retained until a section is completed when all money due on that section will be paid upon certificate from the Engineer that work on said section has been completed in accordance with these specifications.

BOND.

KNOW ALL MEN BY THESE PRESENTS:

That we ....

....as principal and

....

....

as suret.... are held and firmly bound unto the County Commlssioners of Harford County, State of Maryland, in the sum of thirteen thousand dollars, to be paid to the said County Commissioners, or their certain attorney,

their successors and assigns for which payment well and truly to be made, we bind ourselves, our heirs, executors and administrators, jointly and severally, by these presents. Sealed with our seals and dated this .... day of ....1901.

THE CONDITION OF THIS OBLIGATION IS SUCH that if the said principal ....

shall well and truly keep and perform all the terms and conditions of the aforegoing contract for improving the county road between Bel Air and Churchville in Harford County, on .... part to be kept and performed, and shall indemnify and .... the said County Commissioners of Harford County as therein stipulated then this obligation shall have no effect, otherwise it shall remain in full force and virtue.

....(SEAL)

....(SEAL)

....(SEAL)

WITNESS....................................

SPECIFICATIONS FOR THE BALTIMORE-WASHINGTON "TURNPIKE."

WIDTH.

The width of the road-bed, including gutters, shall be 20 feet, both in cuts and embankments unless otherwise specified.

GRADING.

The road-bed is to be brought to the grades shown on plan and profile made by the Highway Division of the Maryland Geological Survey, this plan being part of these specifications, in possession of the Road Commissioners of Prince George's county. The maximum grade of first section of the road to be 5 feet in 100.

If there is not enough material within the line of work to form the embankments, extra material shall be taken from such places as may be designated by the Commissioners. Should there be a surplus of material it shall be used in widening the embankments.

The station numbers refer to those used on the plan before mentioned as made by the Highway Division, Maryland Geological Survey, and are 100 feet apart, beginning at or near a point where the road crosses the line of the District of Columbia and continuing consecutively to the end of this section.

EMBANKMENTS OR FILLS.

The earth used for embankments is to be spread in layers not exceeding 12 inches in thickness until the depth indicated on the plan and profile is reached. The price paid for filling is included in that paid for excavation.

SLOPES.

Slopes to embankments in cuts shall be 1½ horizontal to 1 vertical.

CROSS-SECTION.

The cross-section of the road of both cuts and fills is to be as shown on the sketch which is a part of the plan before mentioned. The cross slope of the finished road shall be not less than $\frac{3}{4}$ inch to 1 foot nor over 1 inch to 1 foot.

SHAPING AND ROLLING.

The road-bed throughout its length is to be properly shaped, so that its surface shall conform to that of the finished road. This work may be done with a road-machine or in any other suitable way. When graded or shaped it should be rolled until firm and hard by rolling with a roller weighing not less than 5 tons. Where the grade of the present road remains unchanged the road-bed should be brought to proper shape with gravel. If the old foundation is thick enough, gravel from the sides could be scraped to the center wherever the present road is too flat. All loose material which may be on the old road-bed is to be removed at all such points where the grade has not been changed, before surfacing with gravel.

CULVERTS.

The walls of brick culverts shall not be less than 8 inches thick. The brick are to be laid in cement mortar composed of one part Portland cement and two parts clean sharp sand. The mortar must be used as soon as possible after mixing and in no case allowed to stand over 45 minutes before using. The brick are to be sound hard building-brick.

The covering stones may be of good quality granite or gneiss or equally strong rock not less than 10 inches thick at any point. They may be of any width not less than 12 inches. They are to be laid as closely as possible, crevices filled with spalls and cement mortar.

The bottom of the brick culverts is to be filled to the depth of 4 inches with coarse clean stone not over 4 inches in size, or other hard broken material of a proper size.

The slope of the bottom of the culvert shall be 3 inches in 20 feet.

PIPE CULVERTS.

Pipe culverts are to be built with the ends of the pipe protected by masonry in such a manner as to prevent the earth in the vicinity from obstructing the end of the pipes. All the pipes used must be sound. They are to be laid in a trench properly shaped so that they will have a firm bearing throughout their length.

SURFACING.

After the road-bed has been brought to proper grade and shape it is to be surfaced with a layer of gravel not less than 8 inches thick for a width of not less than 15 feet. The gravel to be used is to be the best bank gravel obtainable in the immediate vicinity of the road, and in no case is to contain over 40 per cent of clay and sand. The average size of the gravel should be about 1¼ inches, and no gravel to be used the longest dimensions of which is over 2½ inches. Whenever it is possible to obtain other gravel that from stream beds or "branch gravel" is not to be used. Before using

any gravel it is to be inspected and approved by the Highway Division of the Maryland Geological Survey.

SPREADING GRAVEL.

The gravel should be put on in two layers of 4 inches, each layer to be thoroughly rolled by a roller weighing not less than 5 tons.

SHOULDERS.

To prevent the gravel from spreading, it should be banked by the best earth at hand, the shoulders and gravel being rolled down together, and in no instance are the shoulders to be higher than the gravel. No roots, stumps or other vegetable materials are permitted in the shoulders.

CLEARING-UP AND REMOVAL OF RUBBISH.

All materials, such as roots, stumps and other rubbish, are to be removed from the road-bed to some nearby point, which the Road Commissioners may indicate, so that the road-bed and slopes will be left in a neat and workmanlike condition.

GUARD FENCES.

Guard fences are to be erected on the edges of steep embankments and at any other points where the safety of the traveling public demands.

Guard fences are to be built in a substantial manner from sound materials. Posts should not be over 11 feet apart. There should be at least 2 cross-rails. The top rail should be not less than 4 inches by 2 inches, or an equally strong piece of lumber. This rail should be about 4 feet from the ground.

Annual Report of the Baltimore County Roads Engineer for the Year Ending December 31, 1901.

LETTER OF TRANSMITTAL.

To the Honorable the County Commissioners of Baltimore County and the Maryland Geological Survey.

Gentlemen:—As directed by Section 197 of Article 3 of Public Local Laws, title "Baltimore County," sub-title "Road Law," as amended by the General Assembly of 1900, Chapter 685, I beg to submit the following report for the year ending December 31, 1901.

Respectfully,

Walter Wilson Crosby,

Towson, Md., *January* 11, 1902. *Baltimore County Roads Engineer.*

The present statement is submitted in accordance with the law which requires that an annual report shall be made to the Board of County Commissioners of Baltimore county, and to the Maryland Geological Survey of the improvements which have been made in each District, and their cost, with a detailed statement of the amount spent for labor and materials on each road.

CONCISE STATEMENT.

Expenditures on the roads for labor and material in the different Districts of Baltimore county.

District.	Road Funds.	Am't. expd. for labor, &c.	Material.	Total.	Balance.
1......	$14277.20	$4861.47	$6792.53	$11654.00	$2623.20
2......	4638.97	2848.22	1855.83	4704.05	65.08 [1]
3......	18042.54	9213.22	5444.13	14657.35	3385.19
4......	6116.92	1710.66	2599.94	4310.60	1806.32
5......	2444.04	1581.66	1012.89	2594.55	150.51 [1]
6......	2807.45	2201.59	534.47	2736.06	71.39
7......	4965.70	4122.64	671.66	4794.30	171.40
8......	9244.05	6335.60	1287.03	7622.63	1621.42
9......	32040.56	22583.00	9227.47	31810.47	230.09
10......	4011.67	3499.85	661.93	4161.78	150.11 [1]
11......	7839.03	6033.65	724.02	6757.67	1081.36
12......	21377.57	12584.43	6105.54	18689.97	2687.60
13......	9434.43	3418.11	3238.78	6656.89	2777.54
14......	5797.49	6408.46	3932.82	10341.28	4543.79 [1]
15......	10167.49	3797.88	2530.83	6328.71	3838.78
Total,	$153205.11	$91200.44	$46619.87	$137820.31	$15384.80

[1] Overdrafts.

Expenditures from General Funds of 1900 and 1901, paid in 1901 and not chargeable to the different Districts.

	1900 Levy.	1901 Levy.	Totals.
County Commissioners Mileage		$986.30	$986.30
Inter-County Bridges		3111.05	3111.05
Street Sprinkler and Repairs on Roller		767.00	767.00
Pd. Albert Weber on acct. of Contract for use of Exp. Crusher	$1717.72	1415.30	3133.02
Pd. Geo. F. Mardin for repairs of Crusher	452.46		452.46
General Expenses, Salary of Engineer, &c	946.93	2010.74	2957.67
	$3117.11	$8290.39	$11407.50

RESOURCES.

Amount of 1900 Levy spent in 1901.		
General Fund	$5295 93	
Special "	14351.44	
		$19647.37
Amount of General Fund, 1901 Levy		33867.00
" Special " " "		135471.00
Amount collected and collectable from different sources for road purposes		1839.98
Extra Special Fund, 13th District		1474.12
Total Fund available in 1901		$192299.47

EXPENDITURES.

Amount spent by Districts in 1901 for labor and material	$137820.31	
Amount spent not charged to Districts	11407.50	
Balances on hand January 1, 1902	43071.66	
		$192299.47

DETAILED STATEMENT.

FIRST DISTRICT.

PETER LINK, *Chairman*,
JAS. F. MIGAN,
LOUIS C. REST,
} *Road Commissioners.*

Roads.	Labor.	Material.
Thistle Factory Road	$ 48.80	$ 200.37
Wilkens Avenue	122.49	850.74
Melrose Avenue	.63	1.25
Paradise Road	67.00	108.47
Maidens Choice Road	37.31	168.00
Edmondson Avenue	157.44	78.53
Gwynn Oak Avenue Ext'd	147.25	158.10
Winters Lane or Avenue	68.89	143.55
Melvin Avenue	9.75	29.74
Old Frederick Road	360.76	226.62
Ingleside Avenue	58.26	42.87
Rolling Road	481.52	791.83
Bloomsbury Avenue	130.51	509.92
Egg Lane	28.86	

Roads.	Labor.	Material.
Fusting Avenue	$ 25.00	
Sunnyside Avenue	3.50	
Kenwood Avenue	22.75	$ 52.50
Bloomingdale Avenue	2.99	
Valley Road	10.00	43.75
Lurman's Road	10.50	26.25
Newburg Avenue	58.10	162.75
Harlem Lane	244.41	85.75
Magruder Avenue	25.24	34.99
Prospect Avenue	6.25	
Beachfield Avenue	8.75	
Gwynns Falls Road	110.18	475.62
Pumpkin Hill Road	81.89	120.00
Half Mile Lane	6.25	
Cherry Hill Road	41.10	196.50
Wethersville Road	96.31	198.00
St. Agnes Lane	51.51	86.25
Dogwood Road	96.26	78.85
Red Hill Road	198.92	382.62
Nunnery Lane	59.75	70.00
Shell Road	54.00	27.00
See Tick Road	15.75	6.00
Oella Avenue	252.79	455.23
Grays, or River Road	118.75	263.46
Westchester Avenue	128.78	97.61
Hollofield Road	113.74	192.94
Montrose Avenue	42.00	282.79
Hollow Road	32.50	
Hilton Avenue	88.95	24.12
Johnny Cake Road	184.98	119.56
Dykes Avenue	10.62	
	$3922.08	$6792.53
Salaries of Road Commissioners	343.80	
Tools, Lumber, &c.	483.16	
Expenditures of which no complete record has been kept	112.43 [1]	
	$4861.47	

Balance of 1900 Levy on hand January, 1901		$ 1323.20
Less amount turned in from this District from the 1900 Levy toward payment of the County Debt, May 31st, 1901		
Amount of 1900 Levy expended in 1901		$ 1323.20
Special fund for 1901		12054.00
Total fund available in 1901		$14277.20
Amount spent for labor, &c.	$4861.47	
Amount spent for material	6792.53	11654.00
Balance of 1901 Levy on hand January 1st, 1902		$ 2623.20

Work was not commenced in one section of this District until late in the season, on account of a disagreement between the Road Commissioner of that section and the County Commissioners as to the price to be paid for road material, which was adjusted about June first, 1901, and since then work has gone on steadily.

[1] The amounts under this heading include bills for work done in 1900, expenditures by the County Commissioners unapproved by the Engineer and small amounts not chargeable to the other items.

The demands of this District are for better roads than are required to satisfy any other section in the county, and there is great need for a steam-roller which is not now available, thus causing the employment of methods inconsistent with economy and the best results.

SECOND DISTRICT.

HENRY ALBERT, *Chairman*, ALBERT GOSNELL, } *Road Commissioners.*

Roads.	Labor.	Material.
Stumpy Lane	$ 74.49	$ 157.23
Rolling Road	23.00	1.05
Windsor Mill Road	194.24	438.20
Dogwood Road	256.37	31.10
Milford Mill Road	5.75	
Old Court Road	332.50	358.96
Winans Distillery Road	236.16	130.07
Pikesville Road	77.34	136.40
Old Wrights Mill Road	98.16	
Mt. Olive Lane	89.00	
Oakland Road	106.01	46.85
Wards Church Road	89.97	138.10
Gladman Road	76.57	63.25
Hernwood Road	95.17	141.15
Deer Park Road	100.31	65.80
Painters Mill Road	83.74	38.00
Liberty Pike (Bridge)	125.00	18.80
Road from Randallstown to Granite		27.30
Old Church Road	75.50	24.00
Odell's Mill Road	30.37	4.80
Offutt Road	60.00	23.67
Dr. Offutt Road	37.88	3.60
Lyon's Mill Road	27.50	
Davis Avenue	28.13	
Granite Road	3.12	7.50
	$2326.28	$1855.83
Salaries of Road Commissioners	229.09	
Tools	15.53	
Expenditures of which no complete record has been kept	277.32	
	$2848.22	

Balance of 1900 Levy on hand January 1st, 1901		
Overdraft of 1900 Levy, May 31st, 1901		$ 10.62
Amount of 1900 Levy spent in 1901		10.62
Amount Appropriated from the General Fund, for use in this District		411.35
Contributions from private parties		200.00
Special Fund for 1901		4017.00
Total fund available for use in this District, since January 1st, 1901		$ 4638.97
Amount spent for labor, &c.	$2848.22	
Amount spent for material	1855.83	4704.05
Overdraft January 1st, 1902		$ 65.08

The roads are in a rough condition owing to improper systems of stoning that have been used in the past. Owing to the small amount of money per mile available on these roads permanent improvement must be extremely gradual.

THIRD DISTRICT.

WILLIAM CLAGGETT, *Chairman*,
E. L BLAND,
S. F. ROCHE,
} *Road Commissioners.*

Roads.	Labor.	Material.
Buck's Avenue	$ 50.75	$ 4.80
Park Heights Avenue	278.65	
Rogers Avenue	117.20	.53
Catholic Church Lane	433.47	1824.10
Woodholme Avenue	49.50	
Watts Avenue	55.00	
Old Court Road	36.75	
Milford Mill Road	35.00	
Campfield Avenue	22.50	
Glen Avenue	37.50	
Patterson Avenue	87.82	
Belvedere Avenue	369.38	389.26
Slade Avenue	229.38	454.00
Greenspring Avenue	639.17	189.50
Hillside Road	387.12	611.16
Valley Road	512.54	1133.10
Pikesville Road	43.89	
Garrison Road	213.06	5.63
Craddocks Lane	140.92	36.25
Dover Road	90.52	100.80
McDonough Road	96.25	
St. Thomas' Lane	46.81	27.50
Rogers Avenue	190.74	98.29
Pimlico Road	593.97	48.88
Washington or Smith Avenue	242.92	23.75
Highland Avenue		12.54
Bare Hill Road	210.34	46.31
Kelly Avenue	340.86	11.18
Smith Avenue	153.63	309.25
North Avenue	38.49	117.30
	$5744.13	$5444.13
Salaries of Road Commissioners	$ 343.77	
Tools	423.80	
Expenditures of which no complete record has been kept	1751.52	
On account of Law Suits	250.00	
Improvement Association, Mt. Washington	700.00	
	$9213.22	

Balance of 1900 Levy on hand January, 1901		$ 3165.75
Less amount turned in from this District from the 1900 Levy toward payment of the County Debt, May 31st, 1901		700.59
Amount of 1900 Levy expended in 1901		$ 2465.16
Amount appropriated from the General Fund for use in this District		1803.38
Special Fund for 1901		13694.00
Total Fund available for use in this District, since January 1st, 1901		$18042.54
Amount spent for labor, &c	$9213.22	
Amount spent for material	5444.13	14657.35
Balance of 1901 Levy on hand January 1st, 1902		$ 3385.19

The difficulties experienced in securing labor in some parts of this District have seriously interfered with the work being done in those sections. Considerable macadamizing however has been done, notably on the Catholic Church Lane, in Pikesville, the Hillside and Valley roads, in Green Spring Valley, and on some of the roads near Mt. Washington. Belvedere Avenue from Park Heights Avenue to Electric Park has been widened and macadamized. Slade Avenue, near Pikesville, is being macadamized. Before putting on the stone here a considerable amount of grading was found necessary, and this has just been completed. The stone will be put on as soon as the weather permits in the spring.

Advantage was taken by one of the Road Commissioners of this District, of the opportunity offered to the different counties by the Highway Division of the Maryland Geological Survey to secure for use in this District a set of plans of the Valley Road, from a point near Stevenson Station to St. Thomas' church, without cost to the county. From these plans the work of improving the grades and road surface was laid out and is now progressing with the promise of excellent results.

FOURTH DISTRICT.

WILLIAM BYERLY, *Chairman* } *Road Commissioners.*
JACOB WORREL, }

Roads.	Labor.	Material.
Dover Road	$ 227.44	$ 245.61
Old Hanover Road	29.87	63.15
Road from Woodensburg to Westminster pike..	47.32	24.22
Dover to Glyndon Road	27.94	277.10
Worthington Avenue	111.60	285.34
Longnecker Road	12.80	61.88
Tufton Avenue	35.13	52.10
Mantua Mills Road	24.56	68.37
Fringer Road	14.37	16.00
Mt. Gilead Road	23.75	2.45
Piney Grove and St. John's Road	57.52	97.15
Byerly Road	22.50	79.00
Ridge Road	19.00	48.75
Berryman Lane	126.17	140.20
Gwynn Brook Avenue	15.04	34.50
Church Road	46.25	78.25
Toll Gate Road	24.00	33.00
Road from Delight to Timber Grove	19.00	15.00
Bonita Avenue	53.14	86.18
Road between Old Church and Nicodemus	11.88	
Central Avenue	25.00	106.72
Deer Park Road	30.00	38.00
West Point Road	13.75	38.90
Nicodemus Road	53.87	106.28
Garrison Forest Road	42.50	202.40
Painters Mill Road	31.56	18.00
Cocker's Mill Road	67.79	65.06
Dollfield Road	35.94	50.62
14 Mile House Road	25.60	33.00
Cherry Hill Road	35.05	37.20
Bond Avenue	68.38	17.55
Chatsworth Avenue	80.25	96.90

Roads.	Labor.	Material.
Caves Road	$ 3.75	$ 21.06
Pleasant Mill Road		60.00
	$1462.72	$2599.94
Salaries of Road Commissioners	$ 239.60	
Tools	8.34	
	$1710.66	

Balance of 1900 Levy on hand January 1st, 1901		$ 286.53
Less amount turned in from this District from the 1900 Levy toward payment of the County Debt, May 31st, 1901		282.53
Amount of 1900 Levy expended in 1901		$ 4.00
Amount appropriated from the General Fund for use in this District		308.92
Special Fund for 1901		5804.00
Total fund available for use in this District, since January 1st, 1901		$6116.92
Amount spent for labor, &c	$1710.66	
Amount spent for material	2599.94	4310.60
Balance of 1901 Levy on hand January 1st, 1902		$1806.32

The principal material used on the roads in this District is hand-broken flint stone, from which it is impossible to secure the best results. Some limestone has been used within a limited area, but the demands for this material for other purposes prohibit its extensive use on the roads. The roads in the western part of the District benefit from the location of a stone-crusher there, in a quarry of very desirable material.

Early in the year a delegation of citizens made an unsuccessful effort to obtain from the county a stone-crusher and a steam-roller for use in the District. Their failure to secure the same has materially interfered with the work this year.

FIFTH DISTRICT.

LEWIS A. GORSUCH, *Chairman*, } *Road Commissioners.*
WILLIAM S. KEMP,

Roads.	Labor.	Material.
Mt. Carmel and Shamburg Road	$	$ 20.00
Yeoho Road	105.12	62.95
Yeoho and Harford Road	31.31	43.75
Stringtown Road	21.56	21.00
Beckleysville Road	96.34	100.62
Deep Run Road	39.85	3.00
Mill Road	6.13	11.25
Falls Road	99.88	65.87
Shamburg Road	204.23	28.97
South Beckleysville Road	36.37	177.23
Upper Beckleysville and Hampstead	8.87	13.00
Fareston Road	45.25	
Davisville and Yeoho Road	40.37	22.40
Middletown Road	54.92	13.88
Benson's Mill Road	30.34	12.80
Cedar Grove Road	20.25	20.00
Black Rock Road	89.22	14.00
Trenton Road	84.47	181.75

Roads.	Labor.	Material.
Road from Trenton Mill to Carroll County	$ 19.62	
Road from Black Rock to Falls Road	13.87	$ 11.98
Road from Zion Church to Dover Road	10.30	6.00
Grave Run Road	3.93	4.00
Zion Road	20.75	121.98
Road from Beckleysville Road to Falls Road ..	.63	4.80
Resh's Mill Road	13.50	4.00
Pleasant Meadow Road	26.36	2.25
Road from White House to Falls Road..........	5.49	
Dover Road	56.06	37.92
Grace Road	13.43	2.25
Ridge Road	6.06	7.74
Parkton Road	.63	7.50
Road from Trenton Road to Dover Road	16.25	
	$1221.36	$1012.89
Salaries of Road Commissioners	$ 229.14	
Expenditures of which no complete record has been kept	131.16	
	$1581.66	

Balance of 1900 Levy on hand January 1st, 1901....................................		$ 81.40
Less amount turned in from this District from the 1900 Levy toward payment of the County Debt, May 31st, 1901...		1.90
Amount of 1900 Levy expended in 1901..		$ 79.50
Amount appropriated from the General Fund for use in this District		268.36
Contributions received from private parties......................................		225.18
Special Fund for 1901..		1871.00
Total Fund available in 1901..		$2444.04
Amount spent for labor, &c..................................	$1581.66	
Amount spent for material....................................	1012.89	2594.55
Overdraft January 1st, 1902..		$ 150.51

This District with some of the other districts in the northern part of the county suffered severely from the washing rains. Some of the roads and bridges have been entirely washed away, requiring their reconstruction at a large expense.

The small amounts per mile available for use on the roads of this District prevent more being done than the repairs annually necessary to keep the roads and bridges in a passable condition.

SIXTH DISTRICT.

FRANK P. GORE, *Chairman*, } *Road Commissioners.*
GEO. W. HOSHALL,

Roads.	Labor.	Material.
Road from Hoffmanville to Ruhls	$ 15.61	
Hoffmanville to Pa. Line	12.50	
Middletown to Hoffmanville	164.45	$ 29.30
Middletown to New Freedom	7.19	
Rockdale to Ruhls	74.36	
Road by Gunpowder Paper Mills	14.90	
Bentley to Freeland Road	15.00	

Roads.	Labor.	Material.
Middletown to Stiltz	$ 9.24	
Freelands to Gore's Mill	15.00	
Middletown to Walker's Station	40.62	
Eklo to Hoffmanville	28.75	
Keenys to Pa. Line past Ruhl's	11.25	$ 2.22
Keeny's Mill to Pa. Line	111.26	55.78
Freeland Road	2.25	
Middletown to Freelands	126.86	38.35
Middletown Road	4.37	
Middletown to Pa. Line	60.23	19.75
Middletown to Pa. Line past Ruhl's	8.68	7.35
Middletown past Gore's Mill	24.12	76.56
Rayville to Middletown	17.25	
Bentley to Middletown	24.00	
Rockdale to Stiltz	23.92	
Beckleysville to Hoffmanville	5.00	
Road from Middletown Road to Freelands Road.	23.25	53.88
Road from Oakland to Freelands	21.25	
Rayville to Bentley	209.02	82.70
Road from Bentley Road to Walker Road	19.02	30.85
Mackey's Road to Gore's Mill	20.63	
Road from Mt. Zion to Freelands	11.25	
Walker Road	5.75	
Road from Mt. Zion to Dar	27.50	
Walker Road to Bentley Springs	72.50	
Road from New Freedom to Ruhl's	4.37	9.00
Rockdale to Hoffmanville	5.62	
Middletown to Beckleysville	147.20	23.15
Beckleysville to Rockdale	120.14	
Shamburg and Parkton	10.94	
Rayville to Beckleysville	71.94	
Rayville to Walker's Lane	63.92	
Rayville to Parkton	15.00	
Rayville to Shamburg	36.27	
Middletown to Mt. Carmel	114.69	90.58
Hoffmanville to Alesia	19.38	
Rayville to Shock's Barrack	11.63	
Parkton to Beckleysville	68.99	15.00
Road from Graves Run to Lander's Store	17.59	
	$1934.66	$ 534.47
Salaries of Road Commissioners	208.33	
Law Suits	15.00	
Expenditures of which no complete record has been kept	43.60	
	$2201.59	

Balance of 1900 Levy on hand January 1st, 1901		
Overdraft of 1900 funds, May 31st, 1901		$ 2.75
Amount of 1900 Levy expended in 1901		$ 2.75
Appropriated from the General Fund for use in this District		1344.70
Special fund for 1901		1460.00
Total Fund available in 1901		$2807.45
Amount spent for labor, &c	$2201.59	
Amount spent for material	534.47	2736.06
Balance of 1901 Levy on hand, January 1st, 1902		$ 71.39

This District was one of the heavy sufferers from the summer floods. The fund of this District does not permit much permanent work being done, and necessarily has been used largely in patching the worst places in the roads.

SEVENTH DISTRICT.

H. MILTON SLADE, *Chairman*, J. KELLER DOWNS, } *Road Commissioners.*

Roads.	Labor.	Material.
Road from York Road to Harford Line	$ 40.00	
Road from Ross Bond's to Harris' Mill	7.00	
Road from Harris' Mill to Gorsuch Mill	56.25	
Road from York Pike to Old York Road at Jordan's	12.75	$ 29.16
Road from Jordan's to Union School House	12.75	
Road from Crumps to McCoy's Shops	73.25	
Road from McCoy's Shops to Pa. Line	25.30	
Road from Shane to Road from Kirkwood's Shops to Harford Line	4.88	
Road from McCoy's Shops to Gorsuch Mills	6.25	
Road from Five Forks to Road to Bee Tree Switch	10.63	
Freeland Road	110.95	7.45
Road from Pa. Line to Heathcote's Mill	24.07	
Road from Heathcote's Mill to Freeland Road.	15.00	
Road from Old York Road to Road at Stabler's Race	31.00	
Road from Stabler's Church to York Pike	47.59	
Road from Stabler's Church to Pike near Parkton	8.75	
Road from Walker's Station to 6th District Line	104.13	.86
Road from York Pike to Bentley	39.46	
Road from York Pike to Turner's Crossing	33.80	26.88
Road from York Pike to Walker's Mill	9.63	96.89
Road from Old York Road to Gorsuch Mill	33.75	327.25
Road from York Pike at Hoffmanns to Five Forks	40.44	
Road from Five Forks to Cameron's Mill	23.25	
Road from York Pike to Cameron's Mill	17.61	15.60
Road from New Market to Harris' Mill	66.25	12.00
Oakland Road	33.87	24.96
Road from Greens Cross Road to Liberty Church	15.00	
Road from Old York Road to York Pike at Lewins	25.30	
Greystone to Shane	317.85	16.88
Stablersville to Shane	8.75	
Stablersville to Gemmil's	85.07	
White Hall to Harford Line	159.59	39.60
Dairy Road Parkton to Rayville	83.63	
Monkton to Hereford	252.62	36.00
Old York Road	119.86	
White Hall to Falls Bridge	7.50	
White Hall to Wiseburg	63.50	
Blue Mount Road	68.20	
White Hall to Greystone	71.38	
Hereford to Macemore's Mill	24.97	33.13
Road from Old York Road past Garrett's	36.94	

Roads.	Labor.	Material.
Road from Mt. Carmel to Parkton	$ 32.25	
Road from Hereford to Evna	8.50	
Road from York Pike to Bridge at Gorsuch Mill	6.25	
Parkton Paved Road	27.17	
Road from Hereford to Red End	42.57	
Road from White Hall to Hereford	22.50	
Road from Hale's to Wm. Miller Road	28.13	
Road from Hereford Road to Piney Hill	13.00	
Road from Monkton Road to Piney Hill	41.37	
Road from Wiseburg to Burkes Mill	15.00	
Road from Miller's Bridge to Cooper s School House	19.50	$ 5.00
Road from Parkton to Middletown	5.50	
Road from Gillets to York Pike	55.75	
Tyson Road	12.00	
Road from Hunter's Mill to Rail Road	15.00	
	$2513.26	$ 671.66
Salaries of Road Commissioners	227.22	
Tools	35.61	
Expenditures of which no complete record has been kept	1346.55	
	$4122.64	

Balance of 1900 Levy on hand January 1st, 1901		
Overdraft of 1900 Fund, May 31st, 1901		$ 12.80
Amount of 1900 Levy, spent in 1901		$ 12.80
Appropriated from the General Fund for use in this District		2558.90
Special Fund for 1901		2394.00
Total Fund available 1901		$4965.70
Amount spent for labor, &c	$4122.64	
Amount spent for material	671.66	4794.30
Balance of 1901 Levy on hand January 1st, 1902		$ 171.40

This District was probably the heaviest sufferer from the summer floods, a large number of bridges having been washed away. These have all been repaired and some special appropriations from the General Fund have been made for the use of certain roads of the District. These appropriations have been made and the work done entirely without the advice or knowledge of the Engineer, which accounts for the large sum marked "Expenditures of which no complete record has been kept" in the foregoing statement.

EIGHTH DISTRICT.

JOHN T. CHILCOAT, *Chairman*,
MICHAEL PADIAN,
GEORGE ZINK,
} *Road Commissioners.*

Roads.	Labor.	Material.
Sparks Road	$ 11.94	$ 5.20
Belfast Road	277.48	104.19
Road from Cold Bottom to Yeoho Road	11.38	4.48

Roads.	Labor.	Material.
Road from Mantua Mills to Dover Road	$ 83.51	$ 107.80
Corbett Road	76.78	44.64
Glencoe Road	75.64	30.50
Road from Bosley's Church to Western Run Pike	18.63	22.05
Falls Road	255.67	31.80
Tanyard Road	26.69	24.60
Road from Belfast to Yeoho Road	12.55	23.20
Wheelers Lane	43.74	28.40
Wheelers Lane to Western Run Pike	10.00	
Oregon Road	101.56	77.80
Cold Bottom Road	44.50	19.60
Ensor Mill Road	28.50	
Dover Road	207.84	9.00
Priceville Road	138.36	56.98
Stringtown Road	40.82	30.40
Quaker Church Road to Bosleys	4.62	7.80
Phoenix Road	57.79	
Yeoho Road	29.20	
Mantua to Shawan	2.50	
Davisville Road	80.47	73.22
Davisville to Western Run Pike	10.00	
Piney Hill to Corbett	62.73	24.58
York Pike to Monkton		30.40
Road from Cold Bottom Road to Stringtown Road	68.50	
Timonium Road	155.25	11.67
Ridge Road	492.00	
Road from Bosley to Merryman's Corner	31.25	14.40
Ridge Road to Mays Chapel	212.75	10.00
Mays Chapel Road	20.00	
Pot Spring Road	237.51	
Seminary Avenue	48.50	38.85
Mays Hill on Road from Ridge Road to Mays Chapel	32.56	
Texas Lane	4.50	50.70
Beaver Dam Road	280.67	22.90
Warren Road	647.30	172.10
Ivy Hill Road	158.62	44.25
Tufton Avenue	57.19	46.67
Road from Geo. Merryman's to Cross Road	15.37	8.00
Quaker Lane	9.06	22.80
Sherwood Road	18.74	
Texas Road	145.17	
Road past Poplar Church	30.75	
Ander Road	40.00	
Road from Warren to Merryman's Mill	76.75	59.30
Papermill Road	18.75	
Ashland Road	12.50	
Sherwood Church Road	20.50	8.75
Road from Shawan to Carver	6.50	
Ashland Road to Sweet Air	21.25	20.00
Road from Meredith's Ford Bridge to Merryman's Mill	10.63	
Phoenix Avenue	1.50	
	$4586.97	$1287.03

Salaries of Road Commissioners	$ 374.85
Tools	47.57
Law Suits	550.00
Expenditures of which no complete record has been kept	776.21
	$6335.60

Balance of 1900 Levy on hand January 1st, 1901		$ 160.79
Overdraft of 1900 fund May 31st, 1901		214.26
Amount of 1900 Levy spent in 1901		$ 375.05
Appropriated from General Fund for use in this District		1210.23
Contributions received from private parties		12.77
Special Fund for 1901		7646.00
Total Fund available for 1901		$9244.05
Amount spent for labor, &c	$6335.60	
Amount spent for material	1287.03	7622.63
Balance of 1901 Levy on hand January 1st, 1902		$1621.42

Owing to an accident to one of the Road Commissioners of this District, disabling him for some time, little work has been done in his section. In the other precincts the work has been mainly that of repairing the roads and bridges.

The Engineer has several times recommended that advantage be taken of the offer made by some of the residents on Seminary Avenue to pay for the material necessary for top dressing this road, provided the county would pay for putting it on the road. It is to be hoped that this offer will be accepted this year.

NINTH DISTRICT.

THOS. G. STEVENSON, *Chairman.*
JAMES M. ERDMAN,
G. P. SHEPPERD,
} *Road Commissioners.*

Roads.	Labor.	Material.
Hillen Road	$ 1831.84	$ 2114.17
Woodburne Avenue	24.52	
Walker Avenue	41.15	3.90
Regester Avenue	79.25	2.25
Arlington Avenue	369.92	1775.79
Grindin Lane	111.68	66.70
Hamilton Avenue	1088.77	447.21
Bellona Avenue	482.13	26.20
Brightside Avenue	319.76	70.25
Cold Spring Lane	138.76	68.13
Roland Avenue	658.40	1194.48
Gittings Avenue	319.03	649.10
Joppa Road	435.87	112.80
Ruxton Road	399.26	119.63
Chesapeake Avenue	253.51	685.20
Imwold Road	102.87	
Pennsylvania Avenue	366.86	330.56
Belvedere Avenue	75.38	
Washington Avenue	319.28	208.49
Susquehanna Avenue	15.94	.60
Allegheny Avenue	7.50	

Roads.	Labor.	Material.
Baltimore Avenue	$ 51.00	
Ware Avenue	12.50	
Hunt's Road	40.25	
Lutherville Road	37.00	
Lynhurst Avenue	43.25	
Malcolm Road	28.75	
Lake Avenue	275.25	$ 216.58
Mt. Washington Road and Bridge	6.00	46.96
Delaware Avenue	452.65	380.57
Valley Road	1073.10	131.50
Stevenson's Lane	465.73	129.44
Holliday Lane	62.25	18.90
Pleasant Plains Road	143.13	
Virginia Avenue	40.76	87.63
Cowpens Avenue	100.92	28.75
Setter Hill Road	47.10	18.50
Millers Lane	45.00	
Old Harford Road	939.56	184.55
Providence Road	572.87	20.00
Burke Avenue	7.50	44.75
York Pike		2.68
Taylor Avenue	198.60	41.10
McCurdy Avenue	304.52	
	$12,389.46	$ 9,227.37
Salaries of Road Commissioners	339.20	
Tools	210.19	
Work done for private parties	160.89	
Expenditures of which no complete record has been kept	9,483.26	
Total	$22,583.00	

Balance of 1900 Levy on hand, January 1, 1901		$ 4,298.19
Overdraft of 1900 Levy, May 31, 1901		583.87
Amount of 1900 Levy spent in 1901		$ 4,882.06
Contributions received from private parties		667.03
Amount due for rent of Roller (not yet collected)		660.00
Appropriated from the General Fund for use in this District		3,821.47
Special Fund for 1901		22,010.00
Total Fund available for 1901		$32,040.56
Amount spent for labor, &c.	$22,583.00	
Amount spent for material	9,227.47	31,810.47
Balance on hand, January 1, 1902		$ 230.0[illegible]

This District has the largest road fund of any in the county. The roads of the District are practically all stone, some in good condition. The demand on the District Fund is principally for maintaining and improving the present roads.

A large amount of material has been used on the roads in the District this year. The west side of Roland Avenue through Roland Park has been macadamized, and is now in good condition. Chesapeake Avenue in Towson has been resurfaced from a point just west of Baltimore Avenue to the west line of the Offutt property. Washington Avenue, from the

York Pike to the Joppa Road, has received a coat of limestone. Lake Avenue, from the Falls Road to the top of the hill, has received a coat of limestone. Gittings Avenue has been macadamized from Charles Street to Bellona Avenue. Belvedere Avenue has been macadamized from Charles Street west, to the top of the hill. The Hillen Road has received several small patches of stone and has been macadamized from Taylor Avenue southerly to the east edge of the Taylor woods. Delaware and Pennsylvania Avenues in Towson have been macadamized. The Lime Kiln Bottom Road has received a large quantity of stone, and the Old Harford Road and the Falls Hill have been top dressed with gravel stone. Prospect Avenue has been opened from the York Road to the Dulaney Valley Pike and partially graded. The amount set opposite Pennsylvania Avenue is largely for grading and macadamizing this Avenue from the York Road to Delaware Avenue. This piece was built as a "Sample" Road and is the most modern piece of road in the county. The amount charged to Delaware Avenue is the cost of completing the work left undone by the previous contractor.

TENTH DISTRICT.

JOSIAH ALMONY, *Chairman,*
C. C. HALL,
} *Road Commissioners.*

Roads.	Labor.	Material.
Bridge near Fitzpatrick	$ 9.25	$ 63.50
Bridge at Monkton	13.50	86.75
Corbett Road	113.49	141.00
Old York Road	115.81	39.60
Wilson and Fitzpatrick Road	27.75	3.52
Manor and Taylor Road	10.94	
Pocock Road	16.25	25.50
Phoenix Road	190.26	63.74
Shepperd Road to Monkton	36.87	
Shepperd to Houcks Mills	15.43	
Monkton to Manor Road	266.14	75.81
Purdue to Wesley Chapel	11.00	
Sparks Road	44.00	
Glencoe to Manor	31.87	
Emery Road	8.75	
Elliotts to Hunters Mill	49.01	
Monkton to Wesley Chapel	38.37	
Houck Road	15.33	
Phoenix and Corbett Road	11.25	
Phoenix to Hartmans Shops	6.25	
Blue Mount Road	24.50	
Pearces Road	6.00	
Hutchins Mill Road	3.00	
Bosley Road	1.50	
Road from Jarrettsville to Dulaney Valley	18.75	
Chestnut Grove Road	1.25	21.40
Dance's Mill to Blenheim	13.78	19.58
Carroll to Phoenix	182.68	19.82
Road from Blenheim to Sweet Air	4.00	3.00
Road from Stabler's Mill to Old York Road	36.75	5.00
Stanbury's Mill Road	86.20	17.32
Sweet Air Road	56.65	
Road from Jarrettsville to Blenheim		16.20

Roads.	Labor.	Material.
Road from Dance's Mill to Chestnut Grove	$ 1.50	$ 5.00
Road from Sunny Brook to Stabler's Mill	4.75	
Road from Weakley's Gate to Shipley's Lane ..	5.00	
Road from Sunny Brook to Phoenix	35.00	1.63
Road from Webster's Corner to Knoebels	24.50	8.00
Road from Marshalls Mills to Sweet Air	9.38	
Road from Blenheim to Chestnut Grove	43.55	20.00
Road from Jacksonville to Phoenix	32.25	
Road from Manor to Sweet Air	98.43	14.56
Road from Sweet Air to Knoebels	41.62	10.00
Stabler's Mill Road	10.88	1.00
Kemp Road & R. R. Crossing	81.03	
Philpot Road	14.25	
Road from Jacksonville to Old York Road	3.00	
Road from Jarrettsville Pike to Stansbury's Mill	31.25	
Stockton Road	30.00	
Road from Chris. Smiths to Jackson Wilson's ..	21.25	
Road from Andersons to Hartman's Bridge	18.25	
Road from Dulaney Valley to Chestnut Grove..	12.25	
	$1984.72	$ 661.93
Salaries of Road Commissioners	187.50	
Tools, &c	8.00	
Expenditures of which no complete record has been kept	$1319.63	
	$3499.85	

Balance of 1900 Levy on hand January 1st, 1901..................................		
Overdraft of 1900 Levy May 31st, 1901..		$ 122.75
Amount of 1900 Levy spent in 1901		$ 122.75
Amount appropriated from the General Fund for use in this District		1199.92
Contributions from private parties		75.00
Special Fund for 1901		2614.00
Total Fund available for 1901		$4011.67
Amount spent for labor, &c....................................	$3499.85	
Amount spent for material	661.93	4161.78
Overdraft of 1901 Levy, January 1st, 1902..		$ 150.11

The road funds of the upper end of this District were largely increased by appropriations made from the General Fund by the County Commissioners for special purposes. Part of this amount was spent by one of the Road Commissioners without consulting the Engineer. The lower end of the District also received amounts from the General Fund, principally for the Carroll Road and the road leading from the southeast to Phoenix Station. The work on the latter road was ordered, directed, and paid for out of the General Fund by one of the County Commissioners, without the co-operation of the District Road Commissioner or the advice of the Engineer.

ELEVENTH DISTRICT.

FRANK J. KEARNEY, *Chairman*,
FRANCIS CARDWELL,
DAVID DE GRUCHY, } *Road Commissioners.*

Roads.	Labor.	Material.
Belair Road	$ 39.95	
Summer House Road	92.18	

Roads.	Labor.	Material.
Franklinville Road	$ 40.97	$ 70.85
Chapman Road	59.89	14.80
Bradshaw Road	198.16	
Old Belair Road	30.25	469.20
Broad Run Road	80.86	22.80
Raffell Road	27.01	
Reynolds Road	20.63	
Swett House Road	130.71	
Forges Road	59.43	
New Cut Road	54.06	
Philadelphia Road	153.96	20.86
Joppa Road	274.39	16.90
Camp Chapel Road	68.70	46.45
Cowenton Avenue	56.49	16.70
Red Line Road	149.96	4.40
Silver Spring Road	82.93	8.70
Spanner Road	72.00	
Hydes Road	58.58	
Fork Road	85.45	
Guyton Mill Road	54.52	
Baldwin Mill Road	119.62	
Pleasantville Road	35.15	
Patterson Road	42.69	
Glenarm Road	63.82	
Manor Road	68.60	
Bottom Road	55.19	
Morgan Mill Road	19.25	6.40
Green's Road	32.01	21.26
William's Road	20.06	
Notch Cliff Road	24.13	
Temples Road	54.50	
Long Green Road	2358.12	4.70
Kane's Road	15.50	
The Old Pike	92.63	
Hartley's Mill Road	58.54	
Old Factory Road	51.62	
	$5002.51	$ 724.02
Salaries of Road Commissioners	343.70	
Tools	64.43	
Law Suits	101.17	
Expenditures of which no complete record has been kept	521.84	
	$6033.65	

Balance of 1900 Levy on hand January 1st, 1901		$ 617.89
Less amount turned in from this District from the 1900 Fund toward payment of the County Debt, May 31st, 1901		138.68
Amount of 1900 Levy spent in 1901		$ 479.21
Amount appropriated from the General Fund for use in this District		2745.82
Special Fund for 1901		4614.00
Total Fund available in 1901		$7839.03
Amount spent for labor, &c	$6033.65	
Amount spent for material	724.02	6757.67
Balance of 1901 Levy on hand January 1st, 1902		$1081.36

Work on the Long Green Road, begun in 1900, was completed in 1901. One of the first trips of the Roads Engineer to this District was made to decide upon the best method of finishing this road. After some unavoidable delay the steam-roller from the 9th District was sent here and the Long Green Road put in first-class condition.

During the fall of 1900, an agreement was made with the residents along the Old Belair Road by the County Commissioners for the county to crush and put on this road such stone as was hauled to and piled along the road at different places by the residents and a contract was made by the Commissioner for such crushing and delivering. Early in 1901 the County Commissioners concluded to discontinue this work, although there still remained a considerable quantity of stone piled along the road by the residents.

TWELFTH DISTRICT.

MICHAEL GAFF, *Chairman*,
J. J. DOTTERWEICH,
G. E. KING,
} *Road Commissioners.*

Roads.	Labor.	Material.
Sixteenth Street	$ 210.50	
Eastern Avenue	2119.21	$ 167.53
Eighth Street	115.50	27.50
Seventh Street	141.87	25.78
Bank Street	429.63	357.64
Clairmount Avenue	392.75	1002.25
First Street (Highland Avenue)	503.37	209.52
Lombard Street	118.10	63.70
Eleventh Street	471.88	111.80
North Point Road	430.07	194.12
Trap Road	562.02	172.38
Wise's Avenue	429.37	382.23
Sparks' Avenue	13.13	
German Hill Road	119.75	107.88
Mount Carmel Road	1012.49	418.06
Third Street	1202.28	1757.23
Fourteenth Street	532.61	508.11
Gough Street	216.39	106.60
Clinton Street	313.75	172.19
Foster Avenue	45.25	
Fifth Street	132.25	16.70
Fourth Street	76.75	14.60
Baltimore Street	195.88	124.25
Pratt Street	90.88	3.00
Canton Avenue	39.25	26.50
Second Street	106.25	5.10
Ninth Street	53.00	
First Avenue	68.75	8.70
Toome Street	61.26	10.20
Bouldin Street	15.75	
Dillon Street	10.50	
Elliott Street	39.50	
Hudson Street	21.25	
Fait Avenue	7.25	
Eastern Avenue	22.50	
Wilson Spring Road	136.47	116.97
Sollers Point Road	115.25	
	$10572.66	$6105.51

Salaries of Road Commissioners	$ 347.05
Tools	80.30
Law Suits	157.68
Expenditures of which no complete record has been kept	1476.74
Total	$12584.43

Balance of 1900 Levy on hand January 1st, 1901		$ 6967.65
Less amount turned in from this District from the 1900 Levy toward payment of the County Debt, May 31st, 1901		5417.08
Amount of 1900 Levy spent in 1901		$ 1550.57
Amount appropriated from the General Fund for use in this District		125.00
Special Fund for 1901		19702.00
Total Fund available in 1901		$21377.57
Amount spent for labor, &c	$12584.43	
Amount spent for material	6105.54	18689.97
Balance of 1901 Levy on hand January 1st, 1902		$ 2687.60

Heretofore practically no stone has been used on the roads in this District, except where used in the shape of paving-stone on some few streets in Highlandtown and Canton. This year crushed stone has been used on the important streets of these two places with good results.

Owing to lack of modern road-machinery in this District, all stone used has been put on after the old method. If a steam-roller were available for this section, it would soon pay for itself in the quantity of work done and the avoidance of long stretches of loose stone on the roads, unavoidable under the old method.

It has been the custom in the past to do considerable work on the alleys of Highlandtown and Canton, such as clearing up filth, etc., and to pay for it out of the road fund. This work properly belongs, and has now been turned over, to the Sanitary Officer.

Third Street has been macadamized between Eastern Avenue and O'Donnell Street and also between Eastern Avenue and Bank Street. Bank Street has been macadamized between First and Third Streets, and Clairmount Street between First and Fifth Streets. Numerous other streets have received coats of stone where needed.

The use of a light roller on newly spread oyster shells has been recommended by the Engineer as well worth the cost, but this recommendation has not been followed.

THIRTEENTH DISTRICT.

JAS. RITTENHOUSE, *Chairman,* }
JOHN BERGER, } *Road Commissioners.*

Roads.	Labor.	Material.
Annapolis Road	$ 331.25	$ 353.20
Maryland Avenue	225.62	338.40
Holland's Ferry Road	82.01	120.40
Washington Road	327.70	1217.25
Union Avenue	67.50	70.00
Wilken's Avenue	95.93	193.18

FOURTEENTH DISTRICT.

HENRY FRANKENBERGER, *Chairman*, } *Road Commissioners.*
MICHAEL SHEELER,
BENJAMIN WILSON,

Roads.	Labor.	Material.
Blue Ball Avenue	$ 88.75	$ 4.20
Kenwood Park Avenue	28.75	
Philadelphia Road	1516.41	3250.25
Boley's Lane	120.01	19.10
Fullerton Avenue	80.50	11.90
Stump's Mill Avenue	66.63	44.21
Road from Putty Hill to Phila. Road	449.59	77.55
Ridge Road	94.10	96.50
Buck's School House Road	152.45	54.68
King's Avenue	59.57	16.20
Rattuck Avenue	38.00	50.11
Hamilton Avenue	106.75	34.60
Red House Road	229.21	31.85
Stone House Road	79.00	37.85
Hazelwood Avenue	79.25	9.80
Southern Avenue	48.25	152.52
Fitch Avenue	96.64	41.50
	$3333.86	$3932.82
Salaries of Road Commissioners	239.60	
Tools	62.60	
Expenditures of which no complete record has been kept	2772.40	
	$6408.46	

Balance of 1900 Levy on hand January 1st, 1901		$1990.34
Less amount turned in from this District from the 1900 Levy toward payment of the County Debt. May 31st, 1901		1603.41
Amount of 1900 Levy spent in 1901		$ 386.93
Amount appropriated from General Fund for use in this District		267.56
Special Fund for 1901		5143.00
Total Fund available in 1901		$5797.49
Amount spent for labor, &c	$6408.46	
Amount spent for material	3932.82	10341.28
Overdraft January 1st, 1902		$4543.79

The Fourteenth District has this year received a special appropriation from the General Fund for macadamizing the Philadelphia Road from Herring Run to the City Limits. The road is not thoroughly satisfactory, though the cost has been excessive. In this case the County Commissioners instructed the Road Commissioner to disregard the advice of the Engineer.

Southern Avenue has also been macadamized. This work is still in progress, and the result, in this case, promises to be satisfactory.

Roads.	Labor.	Material.
Maiden's Choice Road	$ 48.75	$ 48.20
Sulphur Spring Road	38.36	5.50
Lyndon Avenue		7.70
Leeds Avenue	15.00	
Hammond's Ferry Road	195.50	166.97
Sutton's or Catonsville Avenue	166.86	218.00
Avalon Road	235.00	87.31
Gun Road	270.58	129.19
Viaduct Avenue	39.56	63.00
Arlington Avenue	6.50	
Francis Avenue	21.00	
Ridge Avenue	5.00	
Knecht's Avenue	130.74	3.75
Halethorpe Avenue	28.75	
East & South Sts., St. Denis	67.50	16.53
Winan's Avenue	5.00	
Fish House Road	135.75	200.20
Benson's Avenue	8.00	
	$2547.86	$3238.78
Salaries of Road Commissioners	229.20	
Tools	38.51	
Expenditures of which no complete record has been kept	602.54	
	$3418.11	

Balance of 1900 Levy on hand January 1st, 1901		$1015.43
Less amount turned in from this District from the 1900 Levy toward payment of the County Debt, May 31st, 1901		
Overdraft of 1900 Levy, May 31st, 1901		71.88
Amount of 1900 Levy spent in 1901		$1087.31
Amount appropriated from General Fund for use in this District		160.00
Special Fund for use in this District		1474.12
Special Fund for 1901		6713.00
Total Fund available in 1901		$9434.43
Amount spent for labor, &c.	$3418.11	
Amount spent for material	3238.78	6656.89
Balance of 1901 Levy on hand January 1st, 1902		$2777.54

As in the Twelfth District, the Engineer has advised that the more important roads of this District be macadamized, in place of yearly shelling, and the use of shells be confined to those roads where the travel is light.

The work in this District is especially to be commended, the roads having by careful attention been put in good condition. The Washington and Annapolis roads have been permanently improved by the use of properly crushed stone.

The County Commissioners, acting together with the County Commissioners of Howard county, have this year built a bridge across the Patapsco, at the foot of the "Gun Road," near "Avalon," at a cost to date of about $4800, which is one of the best in the county, and will undoubtedly prove a great convenience.

FIFTEENTH DISTRICT.

JOHN GREEN, *Chairman*,
E. J. HERMAN,
ALEX. HUGHES,
} *Road Commissioners.*

Roads.	Labor.	Material.
Old Philadelphia Road	$ 203.18	$ 180.25
Golden Ring Avenue	50.25	
Poplar Road	76.75	82.55
Chase's Road	75.67	35.22
Ebenezer Road	156.88	226.14
Middle River Road	325.37	351.01
Stemmer's Run Road	93.25	12.00
Eastern Avenue	79.80	36.20
Carroll Island Road	238.90	188.44
Boley's Quarter Road	37.31	53.55
Cowenton Road	241.14	220.57
North Point Road	364.76	228.16
Sparrows Point Road	132.74	
Turkey Point Road	308.81	235.72
Back River Bridge	37.81	432.00
Holly Neck Road	8.50	22.50
Bird River Road	410.02	126.63
Race Road	99.75	94.29
Grace's Quarter Road		5.60
	$2940.89	$2530.83
Salaries of Road Commissioners	343.80	
Tools	49.20	
Expenditures of which no complete record has been kept	463.99	
	$3797.88	

Balance of 1900 Levy on hand January 1st, 1901		$ 3455.99
Less amount turned in from this District from the 1900 Levy toward payment of the County Debt, May 31st, 1901		1886.46
Amount of 1900 Levy spent in 1901		$ 1569.53
Amount appropriated from General Fund for use in this District		761.96
Special Fund for 1901		7836.00
Total Fund Available in 1901		$10167.49
Amount spent for labor, &c	$3797.88	
Amount spent for material	2530.83	6328.71
Balance of 1901 Levy on hand January 1st, 1902		$ 3838.78

The roads of this District are generally in good condition, travel being confined to light farm teams, with the exception of the road from Sparrows Point to North Point. This road, owing to its use by parties hauling heavy material from Sparrows Point to the Government Fortifications, has been badly cut up and is in poor condition. Although a considerable sum of money was spent on this road a year or so ago in shelling it, the portion repaired was not properly graded before being coated with shells, and, as a result, is to-day low and in wet weather almost impassable. A special appropriation should be made for this road for the purpose of properly grading it and then coating it with shells.

General Statement.

During the year beginning January 1st, 1901, there has been spent on the roads of Baltimore county the sum of $149,227.81. Of this amount, the sum of $110,854.25 has been spent through the Road Commissioners, and vouchers for the same have been approved by the Engineer. The remaining sum of $38,373.56 has been spent by the County Commissioners.

In the past a considerable expenditure of county funds has been made on private roads which did not belong to the county, but the stopping of this practice by the County Commissioners will result in the saving of a considerable sum of money.

In conclusion it may be said that permanent improvement in the character of the roads must be gradual, and though the macadamizing of as many roads as practicable is desirable, this must not be done until the general repairs for the roads are made. Thus, in some districts, owing to lack of funds, it is advisable to continue to a certain extent the old method of "stoning" a dirt road where the grades are good, with the idea of eventually utilizing the road thus made as a foundation for modern macadam.

The past year has been very destructive to the roads owing to the severe rains coming all at one time. Notwithstanding this, the expenditures have been comparatively small.

This year, owing to lack of funds and the unfamiliarity of all concerned with the law, work was not really commenced until late in the season, but with the balances now on hand for use until the new levy is available, and with better knowledge of the practical working of the new system, greater and better results may be confidently expected.

PART III

REPORT ON THE CLAYS OF MARYLAND

BY

HEINRICH RIES

GREAT SEAL OF MARYLAND

IN RED TERRA COTTA

MADE BY BURNS AND RUSSELL COMPANY BALTIMORE

REPORT ON THE CLAYS OF MARYLAND

BY

HEINRICH RIES

INTRODUCTION.

The following report is the result of field and laboratory work carried on during the past eighteen months.

Maryland has an abundance and variety of clays and shales which are but little known, and one aim of this report is to bring their distribution and character to public knowledge. It has been considered advisable, however, to go somewhat beyond this point for the reason that the inquiries which come into the State Geologist relate not only to the deposits themselves, but also to clays in general; their uses, methods of manufacture, and machinery used in their manipulation.

In spite of the large and unutilized supplies of plastic materials, there is an active and healthy clay-working industry already started within the State, and some of the clays are even exported to other states.

Maryland ranks eleventh in the list of clay producing states, the total value of her production in 1900, according to the statistics gathered, having been $1,711,856. As a producer of pottery, Maryland is seventh.

The following table gives the details of production for the several years since the organization of the State Geological Survey:

BRICK:	1896	1897	1898	1899	1900
COMMON—					
Quantity	144,519,000	116,841,000	120,588,000	111,479,000	117,830,000
Value	$987,706	$702,957	$714,674	$682,247	$724,013
Average per M.	$6.83	$6.02	$5.93	$6.12	$6.14
PRESSED—					
Quantity	4,572,000	5,316,000	5,868,000	14,335,000	4,439,000
Value	$97,426	$92,344	$87,304	$157,918	$60,729
Average per M.	$21.31	$17.39	$14.20	$11.02	$13.46

BRICK, *cont.*:					
VITRIFIED—	1896	1897	1898	1899	1900
Quantity	186,000	150,000	50,000	50,000	74,000
Value	$2,382	$1,200	$600	$700	$595
Average per M....	$12.80	$8.00	$12.00	$14.00	$8.04
FANCY BRICK, value.	$37,300	$35,100	$3,669	$6,997	$9,866
FIRE BRICK, "	$150,655	$141,650	$77,672	$325,812	$321,666
STOVE-LININGS				$32,457	$36,049
DRAIN-TILE, value..	$1,945	$25,524	$1,649	$3,673	$2,363
ORNAMENTAL TERRA COTTA	$5,075	$6,000	(a)		
TILE (not drain)	$27,003	$18,470	(a)		
POTTERY:					
EARTHENWARE AND STONEWARE, value.	$27,696	$127,277	$8,854	$361,726	$436,617
YELLOW AND ROCKINGHAM WARE, value............		$7,740	(a)		
C. C. AND WHITE GRANITE WARE...			(a)		
PORCELAIN OR CHINA			$100,000		
RAW CLAY				$3,955	
MISCELLANEOUS.....	$112,867	$47,020	$359,003	$107,111	$119,958
TOTAL VALUE.	$1,450,055	$1,205,282	$1,353,425	$1,683,596	$1,711,856

(a) Not published, for protection of operators in this line.

A comparison of these figures with those of the total United States production shows that Maryland is a larger producer of clay products than a number of other eastern states, including Alabama, Georgia, Delaware, Maine, New Hampshire, North Carolina, South Carolina, Vermont, Virginia.

For the last six years the total production of clay products in Maryland has risen steadily with the exception of 1897. The totals are as follows:

Year.	Value.	Rank.
1895	$1,066,987	13
1896	1,450,055	10
1897	1,205,282	11
1898	1,353,425	10
1899	1,683,596	11
1900	1,711,856	11

The writer feels that he is much indebted to the many persons who have aided him in the prosecution of the work on the Maryland clays. To Mr. Arthur Bibbins, of the Woman's College in Baltimore, special thanks are due, for, on account of his intimate knowledge of the Potomac formations, much time has been saved in tracing out the different clay deposits. Mr. Bibbins has supplied the writer with a number of samples and data regarding many outcrops, and has also furnished the data for the map showing the areal distribution of the clay-bearing Potomac formations.

Dr. G. C. Martin, of Johns Hopkins University, has supplied much information regarding the Carboniferous in the western part of the State. A number of samples which were collected at different localities have been submitted to chemical and physical tests, the results of these being embodied in the subsequent pages of the report.

On the Origin, Properties and Uses of Clay, with Special Reference to those of Maryland.

The literature dealing with clay, its properties, uses and methods of investigation is so scattered that many books and papers dealing with the subject are often more or less inaccessible, and can either be found only in the largest libraries or have to be specially ordered from the publisher. Furthermore, some of the most important works on the subject which were published some years ago have gone out of print and the publishers have neglected to issue new editions of them. This being the case, and also for the reason that clay is a material which is calling forth so much interest at the present date, and in which so much money is being invested, it has been considered advisable in the several chapters which follow to give more or less information relating to the portions of the subject mentioned in the above title. It is also hoped that this information will serve to answer many of the questions which are continually being addressed to the State Geologist by persons owning clay property or desiring to invest in the same.

DEFINITION OF CLAY.

The ordinary conception of clay is that it is an earthy material which is exceedingly pasty or sticky when wet and that, owing to this

pastiness, or *plasticity* as it is more properly called, the material can be molded into almost any desired shape, such as bricks, pieces of pottery, or terra cotta. This popular idea of clay assumes that its distinctive characteristics are physical ones, and this is indeed true, for in all other respects clay usually shows the greatest variation. On this account more or less difficulty has been encountered in finding a proper definition of the material. It has also led to a rather loose use of the term *clay*. From the mineralogical standpoint, clay may be defined in the words of Dr. G. P. Merrill as "an indefinite mixture of more or less hydrated alumina silicates, free silica, iron oxide, carbonates of lime, and various silicate minerals which, in a more or less decomposed and fragmentary condition have survived the destructive agencies to which they have been subjected." This at once shows us that clays may vary widely in their mineral characteristics, and consequently they will also vary in their chemical composition, so that, indeed, the only property which they all show is that they are plastic when wet and that they become "as hard as rock" when burned. The chemical composition, and also, of course, the mineralogical composition, have probably very little to do with the plasticity of the material usually, for two clays which may show exactly the same amount of plasticity may vary very widely in their chemical make-up.

Origin of Clay.

It is commonly stated in text-books that clay is formed by the decomposition of feldspar, but this statement is only partly true. When feldspar decomposes under the action of weathering, or in rarer cases under the influence of chemical vapors coming up from the earth's interior, it yields a white, powdery material known as *kaolinite*, which is a hydrated silicate of alumina. To the mass of kaolinite the term *kaolin* is given. This is looked upon as the purest form of clay, and since it is also considered by many to be the basis of all clays, the name of clay substance has been sometimes given to it. Since the clay substance proper is very fine in grain, and since impure clays often contain extremely fine fragments of the same

size as the clay substance, the use of the term has broadened considerably and is now often used to include all of the finest grained particles which the clay contains, namely, those under 5/1000 of an inch in diameter. Pure kaolin is almost unknown in nature, and pockets of it have been found in but very few localities. Kaolinite is a secondary mineral which is formed, as already stated, by the decomposition of feldspar, this decomposition taking place when the surface water charged with carbonic acids or other acids attacks the mineral in question. The result of this chemical action is to break up the feldspar into soluble and insoluble compounds, the former being carried off in solution and the latter remaining behind. The feldspars are common minerals found in nearly all igneous and metamorphic rocks, such as granites and gneisses, and chemically they are anhydrous silicates of alumina, which also contain varying amounts of lime, potash and soda. Depending upon the presence or absence and relative quantity of these last three ingredients, it is customary to recognize a number of feldspar species whose characters would be taken into account not only because they form kaolinite with unequal rapidity, but also because they vary in their fusibility. The most important of these feldspar species are as follows:

	SPECIES.	SILICA.	ALUMINA.	POTASH.	SODA.	LIME.
	Orthoclase	64.7	18.4	16.9	..	..
PLAGIOCLASE	Albite	68.	20.	..	12.	..
	Oligoclase	62.	24.	..	9.	5.
	Labradorite	53.	30.	..	4.	13.
	Anorthite	43.	37.	..	..	20.

Any of the above species may by decomposition yield the mineral kaolinite, and the last four decompose more readily under the action of water than the first. Indeed, so marked is this difference that it is sometimes possible to find beds of kaolin formed from the decomposition of rocks containing both kinds of feldspar in which the plagioclase has weathered down to kaolin, while still embedded in it are the nearly fresh fragments of the orthoclase, which yields much more slowly to the weather.

The process that takes place when the mineral such as orthoclase changes to kaolinite is that the feldspar is broken up chemically,

the potash which it contains uniting with the carbonic acid of the surface waters and forming carbonate of potash, while practically all the silica and the alumina which the feldspar had unite with some of the water forming the mineral kaolinite; some of the silica also unites with the water alone and forms hydrous silica, which is known in nature as opal. Most of the kaolin found in nature has been formed by the decomposition of orthoclase, which is much more common than plagioclase. While this process of kaolinization of the feldspar, as it is called, commonly takes place as the result of weathering, still it may also occur, as already stated, through the action of heated vapors coming up through fissures. This is a point which has more than a merely scientific bearing. In the case of a mass of feldspar which has been changed to kaolin if the process has gone on as the result of surface weathering, then the feldspar will only be decomposed to a depth reached by the weathering agents, which may be anywhere from 10 to 60, or even 100, feet (well shown around Northeast, Cecil county). On the other hand, if the feldspar has altered to kaolin as the result of hot vapors coming up through the rocks from below, then the depth of the deposit may be almost unlimited. Deposits of the latter type include some of the most important ones known, and are sometimes found associated with veins of tin ore. It is highly improbable that any of the kaolin deposits found in Maryland are of this nature. So far as is known, all of them are the result of simple surface weathering.

From our present knowledge of the subject of clay, it does not, perhaps, seem safe to assume that all clays are formed from the decomposition of feldspar or from rocks containing a very large amount of this mineral. Indeed it almost seems probable that minerals such as hornblende may by their decomposition break down to the material which possesses the plasticity so characteristic of true clay.

RESIDUAL CLAYS.

When a mass of feldspar or feldspathic rock decomposes under the action of weather, thus forming a bed of clay, it is found on penetrating the deposit from the surface downwards that the finest grained

FIG. 1.—SHOWING METHOD OF MINING DOWN THE DIP.

FIG. 2.—PASSAGE OF GRANITE INTO RESIDUAL CLAY, FRENCHTOWN, CECIL COUNTY.

and the most plastic material is near the top, while farther downwards are the angular grains of undecomposed minerals and rocks, then the larger angular fragments, until finally with increasing depth the solid rock itself is encountered, there being a gradual change from the fully formed clay at the surface to the unaltered or parent rock below. In some cases it is not unusual to find the structure of the parent rock still preserved in the clay deposit. This is a fact that can be observed in many railroad and wagon-road cuttings in the South. In the state of Maryland sections of this type would be especially abundant from a N. E.-S. W. line through Baltimore, westward to the western boundary of Howard and Baltimore counties, for it is in this region that the roads are underlain by gneissic rocks. These often have a banded structure because the dark, scaly minerals like mica and hornblende are separated into bands distinct from the quartz and feldspar, and the individuality of these bands is still noticeable in the clay. Beds of clay of this type, which are found at the locality where they were formed, are known as residual clays and occur in many localities throughout the entire State with the exception of the Coastal Plain region. Except in those cases where the clay has been formed from the decomposition of a rock composed almost entirely of feldspar, these residual deposits are seldom of great purity, and consequently adapted to the manufacture of common brick only. They are usually highly plastic, and their bright red color, together with the ease with which they wash, causes them frequently to attract attention.

While the residual clays found in the State are often impure, at the same time the deposits of this type include some of the most valuable which are worked within the boundaries of Maryland. The great masses of china clay or kaolin, for example, which are known to occur in Cecil county are residual materials derived from the decomposition of the Algonkian feldspathic gneisses in that area. The fire-clay mined near Dorsey is likewise of residual character. Outside of some high-grade deposits of this type, the most of the residual clays found in the State are but little used, although many of them are indeed admirably suited for the manufacture of common brick. These residual materials are treated in a separate chapter.

SEDIMENTARY CLAYS.

It is a well-known fact that almost every rain-storm washes down more or less fine sand and clay from the summits of the hills and the sides of the valleys into the streams and that this material is carried by the streams in suspension until they reach quiet waters such as the lake or the sea, where, owing to the slackening of the current, the sediment is gradually dropped and spread out over the floor of the ocean or lake as a series of layers. There is thus built up a deposit of stratified clay which has been derived in part from the residual clays of the land. These stratified clays, or sedimentary clays as they are called, represent the most extensive type of clay deposits known, and probably all of the clay beds found in the Coastal Plain region, and also those underlying the terraces and flats in the broader valleys of the State, belong to this type.

Sedimentary clays differ much in their structure from residual ones. In the first place they possess stratification as already noted. Secondly, they are likely to be much more homogeneous than residual clays and, as a rule, much finer grained in character, lacking also the coarser angular particles so frequently met with in residual deposits. Their plasticity or pastiness is much greater than the other beds upon which they rest, in other words, there is no gradual downward passage from fully formed clay into undecomposed rock.

The thickness of sedimentary deposits is very variable in the valleys, being often but a few feet thick, since they represent deposits of but local extent, whereas those which have been formed in lakes or on the bottom of the sea may often show a series of layers aggregating several hundred feet in depth. It rarely happens, however, that a deposit of sedimentary clay will be absolutely homogeneous in its character from the top to the bottom of the section, for this would mean the existence of extremely uniform conditions throughout the area in which the material had been laid down. It should also be remembered that the clay sediment brought down by the rivers is not all of the same size of grain, but that it is composed of extremely fine particles, so small that they will float in water for weeks without settling, and also of coarser and gritty particles which

will settle with comparative rapidity. If, therefore, the velocity of the water varies over any one area the material dropped in that area will also vary with it, the smallest particles being dropped when the water is extremely quiet and the coarser ones alone settling down when the ocean is disturbed by wind or other causes. This variation in conditions over the area in which deposition is taking place can very easily have caused the alternations which are found in many of the Coastal Plain deposits. If an examination is made of almost any river such as the Patuxent, the Severn, the Magothy, or any other extending inland from the Bay or ocean shore, the section will show beds first of clay, then, perhaps, of sand, then more clay and so on, sometimes the material becoming so coarse as to contain pebbles. While the examples of this type are extremely numerous, still a few special ones might be mentioned.

On the Severn river, for example, at the site of the Old Severn River Brick Works, there are found large deposits of medium-grained plastic clay which are overlain by beds of very pure sand, suitable for the manufacture of glass, and these in turn grade upwards into deposits which are a mixture of sand and clay. Again, at a locality known as Shannons Hill, near Northeast, in Cecil county, there are to be found several beds of chocolate clay which show a thickness of from four to six feet, but which are separated from each other by several feet of sand or sandy clay, showing that there was a variation in the conditions of deposition in that area when this material was deposited. Similar examples might be quoted from many other points.

This question of variation in texture of deposit has been mentioned in some detail for the reason that it has a practical bearing. If the clay deposit were of great thickness and absolutely homogeneous throughout and covered by very little overburden, the mining of it would then be a simple and economical problem. On the other hand, if there are several beds of good thick clay which, however, are separated by deposits of sand, then in the mining of the material the cost of removing this sand must be considered, and also whether there is not some possible use for it. It may, perhaps, serve for the

filling in, or in some cases it might do to mix with the clay in case the latter shows too great plasticity, or again it may be useful for building purposes or perhaps for molding purposes in iron manufacture.

While beds of sedimentary clay are extremely abundant in the Coastal Plain formations and are often of considerable extent, at the same time one should not lose sight of the fact that these deposits may at times be in the shape of lenses, in other words, they may taper out laterally although in the center they show great thickness. This is a point which should be carefully determined in the opening up of a deposit and before any money is spent in the erection of works for utilizing the material.

While sedimentary clays are frequently very close to the surface, at the same time they may often lie many feet below it and be imbedded with other rocks.

Sedimentary clays sometimes become consolidated under pressure and are then known as *shales.* When the shale has been formed by simple consolidation it is then possible to reduce it again to the powdery clay-like substance by simple grinding, and this mass when mixed with water will show as much plasticity as the original clay. In some cases, however, the consolidation of the shale has been due not only to pressure, but also to the cementing together of the particles by some material such as iron oxide, and thus it becomes a matter of greater difficulty to develop plasticity by mere grinding and mixing with water. The Devonian shales mined near Cumberland are in many cases the result of simple consolidation. On the other hand, some of the shales in the Carboniferous of Allegany and Garrett counties seem to be the result of both pressure and cementation, so that the grinding and mixing in water in either case developes but a lean mass.

Weathering will often reduce a hard shale to a very plastic clay and the mellowed outcrops of many shale deposits are often of considerable value.

When the shale is subjected to metamorphism it is converted into *slate* and the latter cannot be rendered plastic by grinding. The term slate is often erroneously applied by coal-miners to the beds

of black shale which underly the coal seams. When the shale is light gray and somewhat soft it is likely to be called fire-clay, although it is not always refractory in its character.

Shales are known in many different geological formations, and in the State of Maryland the most important ones are to be found in the Devonian and Carboniferous rocks, although shales of Triassic age are also known, but these latter are in most cases too silicious or hard to have much commercial value, although in North Carolina Triassic shales are used in the manufacture of sewer-pipe.

Clays vary so much in their character and are used for so many different purposes that attempts to classify them have usually been more or less unsuccessful. There are, however, several terms descriptive of some particular variety of clay which are often met with and which may perhaps be given here. *Brick-clay* is a term applied to almost any common red-burning clay. *Pipe-clay* is a term used by many people to designate almost any fine-grained plastic clay, most commonly of bluish-gray color. The term is therefore a very loose one. *Fire-clay* is used to designate those clays which are supposed to resist a high degree of heat, but as a matter of fact the term has been much abused and is often applied to clays which have no refractory qualities. *Flint-clay* is a hard, dense clay having a conchoidal fracture and it is highly refractory in its character. It is almost impossible to develope any plasticity in it even by fine grinding.

Mineral Composition of Clays.

Clays may show a very great variety of mineral species, the number contained usually increasing as the purity of the clay decreases. The material which by many is supposed to form the base of all clays is kaolinite, while associated with it in somewhat smaller quantities are often found feldspar, quartz, mica, hornblende, pyrite, garnet, magnetite, calcite, dolomite, gypsum, and other minerals. In some cases, such as mica flakes, the mineral grains are sufficiently large to be distinguished with the naked eye or by means of a hand lens, but usually they are so extremely fine as to permit identification only with the aid of a powerful microscope. Those minerals which sometimes attain macroscopic size are quartz, mica, gypsum, calcite

and feldspar. The characters of some of these more common minerals which are found in clays and clay-like materials are as follows:

KAOLINITE.

The formula of this mineral is Al_2O_3, $2SiO_2$, $2H_2O$; or Silica, 46.3%; Alumina, 39.8%; and Water, 13.9%. The properties of this mineral as given by Dana are that it is a white, pearly mineral, crystallizing in the monoclinic system, the crystals presenting small hexagonal plates; its specific gravity is 2.2 to 2.6; hardness, 2 to 2.5; it is naturally white in color, and a mass of it is plastic when wet. Kaolinite crystals are claimed by many to be present in all clays, but if this is the case it is extremely difficult to distinguish them at times and they do not always show the hexagonal form mentioned. Not infrequently the plates of kaolinite are found to be collected into little bunches and the breaking up of these is found to increase the plasticity.[1] Kaolinite is nearly infusible, but a slight proportion of some flux would at once lower its refractoriness. The mineral kaolinite will naturally predominate in those types of clay which are very nearly free from impurities, and to such materials the name of kaolin has been given. Since in most instances kaolinite is formed from the decomposition of feldspar, and since also its transportation from the point of its origin would tend to introduce foreign mineral matter into it, it is considered best to restrict the term kaolin to those deposits of nearly pure clay which are at the localities of their origin and which burn to a white color. The term nearly pure clay is used above for the reason that up to the present time deposits of absolutely pure clay have not been found.

The plasticity of kaolin is commonly very low and its tensile strength is also weak, being usually from five to fifteen pounds per square inch. (See tensile strength, pp. 260-261, 280-282.)

White mica is a very common impurity in kaolin which sometimes contains such a large quantity of it that the tiny glistening scales of this mineral are at once noticeable.

In the examination of kaolin, especially in making a rational

[1] Clays of New Jersey, New Jersey Geol. Survey, 1878, G. H. Cook.

analysis, it has been the custom to disregard the effect which mica might have on the properties of the clay, many having considered that mica is very much like kaolinite in its behavior and that therefore unless there is an appreciable amount of it in the kaolin its influence need not be considered.

One of the ceramic chemists of Europe, who had given some attention to this matter, came to the conclusion that fine-grained mica possessed a plasticity almost equal to that of kaolinite, and that like the clay substance it tended to remain in suspension for a very long period, and that consequently it was almost impossible to separate the two in washing. He also considered that white mica and kaolinite were similar in their refractoriness from the fact that the latter was unaffected by a temperature of as much as 2425 degrees Fahrenheit. Up to this point the two minerals may indeed act alike, but if the temperature be raised still higher then the difference in refractoriness of the two can at once be seen, for the reason that at a temperature of cone 27, whose fusing point is about 3000° Fahr., the kaolinite shows not the slightest indication of fusion, whereas white mica at this point melts down to a transparent glass. The two minerals, therefore, cannot be looked upon as agreeing in all their properties.

Associated with the kaolinite there are sometimes other hydrated silicates of alumina which are sometimes crystallized but at other times are of amorphous form. These latter have been described as different species, but whether they are really such may be open to doubt. Among these other minerals of the kaolinite group may be mentioned: *Halloysite,* which is a massive clay-like or earthy mineral with a conchoidal fracture; *Rectorite,* a monoclinic mineral somewhat resembling talc in appearance; *Newtonite,* found in rhombohedral crystals and forming compact masses resembling kaolinite; *Allophane,* which forms amorphous incrustations. *Indianaite* is a white residual kaolinitic mineral found in St. Lawrence county, Indiana, and is regarded by Dana as a variety of halloysite.

QUARTZ.

Quartz is found in both residual and sedimentary clays, being present in the former usually in the shape of angular particles and

in the latter commonly as rounded grains and usually of much smaller size. In most cases the quartz grains are colorless, but owing to the superficial coating of hematite or limonite they may appear either reddish or yellow. In many of the Cretaceous and Tertiary clays of the Coastal Plain, notably in those found in the Raritan or more especially the Patuxent formation, quartz grains are exceedingly abundant, sometimes being present in such quantity as to give the material the character and appearance of a sand rather than a clay. In such sandy clays the plasticity is often quite low, the fire shrinkage is also very small, and the material may require very little water to mold it. Clays of this type have been used to some extent for making terra cotta and considerable silicious clay was obtained at one time from the Patuxent formation in the digging of the Court-house foundations in the City of Baltimore.

When sufficiently large to be seen with the naked eye or by means of the lens the quartz grains are often quite easily recognized on account of their glassy lustre, transparent appearance, and conchoidal or shell-like break or fracture. They are extremely hard and consequently will scratch glass very easily. On this account the material is sometimes used for abrasive purposes and many very sandy clays have found application in this direction, being employed as an ingredient of scouring soaps and sands. When the percentage of clay disappears almost entirely, leaving nothing but quartz grains, the material then finds application in the manufacture of glass, fire-sand or fire-mortar. In many deposits occur alternating layers of beds of quartz sand and layers of very quartzose clay. The glass-sand deposits near the head of the Severn river, in Anne Arundel county, are examples of this type. At other localities the clay instead of passing upwards or downwards into a bed of quartz sand may grade horizontally into the latter material, in which case the clay deposit is often likely to be lens-shaped.

In addition to the effects on clays mentioned above, it also exercises a certain influence on the fusibility of the material. At low temperatures the quartz acts as a refractory agent tending to oppose the fusion of the clay, but at high temperatures quartz is a flux,

tending to decrease the refractoriness of the material and consequently for very refractory clays a high silica content is undesirable.

FELDSPAR.

This is a mineral which often occurs associated with quartz in almost every clay, and might perhaps in some cases be mistaken for it. It differs from it considerably, however, mineralogically and also in its general effects on the behavior of the clay on heating. Feldspar chemically is a complex silicate of alumina with potash, or lime and soda. It is divided into a number of species which have a more or less constant chemical composition. In general feldspars may be distinguished by their considerable hardness, although it is not as great as that of quartz, and by their pronounced cleavage, which tends to make the fragments break off along flat surfaces, which, when the mineral is fresh, are bright and lustrous. The principal species of feldspar, together with their composition, are as follows:

SPECIES.	SILICA.	ALUMINA.	POTASH.	SODA.	LIME.
Orthoclase	64.7	18.4	16.9	..	..
Albite	68.	20.	..	12.	..
Oligoclase	62.	24.	..	9.	5.
Labradorite	53.	30.	..	4.	13.
Anorthite	43.	37.	..	..	20.

Of the above species, orthoclase is perhaps the commonest and is usually of a pink, red, or yellowish color. Next to this come the other species which are known collectively as the plagioclase or lime-soda feldspars.

The orthoclase feldspar is common in granitic rocks while the plagioclase feldspar is more abundant in the basic or dark-colored igneous rocks such as gabbros and diorites. One should therefore expect to find orthoclase grains in those clays which have been derived from granitic rocks and plagioclase grains in those clays which have been derived from rocks of the gabbro or diorite type. Residual clays of both these types occur in the State of Maryland, those which are mined at Dorsey and near Northeast coming from granite, while those which occur abundantly on the surface near Catonsville have been derived from gabbro.

Whatever the type of feldspar, the effect of the weather on it is the same in all cases. It breaks it down into clay. Feldspar decomposes rather readily, and the first evidence of its decomposition is a loss of lustre on the surface of the crystals or cleavage planes; secondly a milky appearance on the surface and also along the cleavage cracks of the mineral showing that the change of the feldspar into clay has already begun. While all types of feldspar seem to change rather rapidly to clay, still those of the plagioclase type seem to weather more rapidly than the orthoclase feldspars. The decomposition product derived from the feldspar is the white powdery mineral previously described, kaolinite.

CALCITE.

This is a mineral which is extremely abundant in many clays, especially those of a marly nature, as would be the clays in many of the Tertiary deposits found in the lower counties bordering on Chesapeake Bay. Calcite commonly occurs in clay in the form of tiny crystals, often so small that it is difficult to recognize them except with the highest powers of the microscope. In rare instances it is found in the clay in the form of little rhombohedral grains.

Sometimes the grains of calcite have collected together in the clay in the form of concretions, or "clay-dogs" as they are sometimes called. The presence of calcite or carbonate of lime in the clay may be determined in several different ways. The simplest is to put a drop of muriatic or other weak acid on the clay, whereupon effervescence ensues, even if the percentage of carbonate of lime is but three or four per cent. The presence of "clay-dogs" or, more often, shell fragments, may lead us to suspect that the clay contains carbonate of lime. Limestone pebbles found in some clays may also indicate the presence of lime carbonate. The fact, however, that the clay is formed by the decomposition of limestone does not necessarily mean that it is highly calcareous. Analyses made of the residual limestone clay at different depths below the surface indicate that the percentage of carbonate of lime may be very low until a point close to the parent rock is reached, when the

quantity of carbonate of lime is suddenly increased. This is, of course, easily understood, for carbonate of lime is quite soluble in rain water, which often contains more or less carbonic acid and is, therefore, more readily leached out of the clay. The springs issuing from such a clay bank are often " hard " on account of the percentage of lime which they contain.

MICA.

Mica is one of the most abundant minerals found in the clays of Maryland, there being but few deposits which do not show some grains of mica, even though they contain only a small quantity. Mica can usually be detected on account of its occurring in the form of small shining scales, the reflection from which at once catches the eye. The mica which is found in clays is commonly derived either from igneous or metamorphic rocks such as granites, gneisses or schists. Two kinds of mica are commonly found in the clay, namely, biotite, or dark mica, and muscovite, or white mica. The biotite is a silicate of iron, magnesia and alumina, whose form is that of six-sided plates or irregular scales, usually of a dark color. It decomposes readily on exposure to the air, yielding limonite or iron rust, and therefore does not remain in its fresh condition as long as the muscovite. The latter is sometimes called the potash mica, although it may also contain a small amount of iron and magnesia. It is of a silvery white or light brown color.

When the clay is subjected to a washing process the small scales of mica float off very readily with the clay particles, and are consequently very hard to remove by washing. In a mechanical analysis the grains of mica are to be found in nearly all of the products of separation from the clay grains up to the fine sand, since the mica scales vary much in their size.

The effect of mica on clays is highly interesting, but it has seldom been given much consideration by persons investigating this material. In a rational analysis of clays, the method which was first brought out in Europe, it has been common to regard the mica as similar to the kaolinite in its properties and general behavior, and consequently no attempt has been made to separate it. Only a few years ago

George Vogt, the ceramic chemist of the Sevres Porcelain Works, in making some experiments with kaolin containing mica came to the conclusion that mica was very similar to kaolinite in its behavior, that is, he claimed the finest grains of mica had a plasticity equal to that of kaolinite; they were also very refractory, being unaffected according to his experiments by a temperature of between 1300° and 1400° Centigrade. Since most of the European kaolins contain very small quantities of mica, the true nature of that material was scarcely noticed and it was common to lump it in with the clay substances. In the United States, however, many kaolins found are quite micaceous and therefore a good opportunity is afforded to observe the effect of the mineral.

The experiments of the writer have brought out several facts which are somewhat at variance with those usually seen in print and which are more in the nature of suggestions than of definite statements. In the first place none of the common micas are at all highly refractory. Owing to its smooth, bright surface the mica seems to resist fluxing action in the clay to a moderately high temperature, that is, to about 2300° or 2400° Fahr. Clay samples containing mica scales burned to this point have often shown this mineral in a comparatively unaltered condition. If heated above this point, however, the mica seems to lose its lustre and in some cases it seems to lose it at even a lower temperature. In order to test the refractoriness of the material four kinds of mica: namely, phlogopite, biotite, lepidolite and muscovite, were heated in the Deville furnace, to cone 27, at which temperature every one of them had melted to a glass, thus showing that none of these four common species are refractory in the true sense.[1]

Another effect of mica seems to be to lower the plasticity of the clay. It has invariably come to the notice of the writer that those clays which contain a large quantity of mica, even though this may be in a very finely divided condition, are invariably of low plasticity. They are also of low tensile strength and this effect becomes very

[1] This work was done in connection with a Barnard Fellowship investigation at Columbia University.

The Friedenwald Co.

CLAY BANK SHOWING CARBONATE OF IRON CONCRETIONS, REYNOLD'S ORE BANK, ANNE ARUNDEL COUNTY.

marked with an increase of the mica. It is, therefore, not safe in making a rational analysis of a kaolin which contains considerable quantities of mica to consider this latter mineral as playing the part of the true clay substance or kaolinite. Even though we wished to do so, the ordinary method of rational analysis as at present carried out would not yield truthful results, and some special means would have to be devised for extracting the mica separately. Kaolinite is decomposed by treatment with sulphuric acid. The white mica or muscovite is not decomposed by this treatment and this seems to be the species usually present in kaolin.

In the clays of the Coastal Plain formations of Maryland, mica is at times quite abundant, especially in many of the clays occurring in the Patuxent formation of the Potomac. This excess of mica in these clays is not surprising for the reason that they have naturally been derived from the residual material of the gneisses of the Piedmont Plateau, which are often highly micaceous. When a micaceous gneiss decomposes under the action of the weather, the mineral which is most effected is the feldspar. This crumbles down easily to clay; the quartz grains will not decompose but they may break up by disintegration into fine particles, each of which, however, retains its individual freshness. The muscovite mica containing no iron which will rust out easily and having a very smooth surface does not weather so readily even if all the feldspar has been decomposed to clay, and thus often in the fully formed deposits of kaolin the bright mica scales may still be found.

IRON OXIDE.

This is one of the most abundant constituents of clay. In fact there is perhaps hardly a clay which does not contain a certain amount of it, although the percentage of ferric oxide may range from one- or two-tenths up to 10 or 15 per cent. When it gets much above this the material is usually called ochre or, if the percentage is very high, low-grade iron ore.

The iron oxide sometimes occurs in the form of grains, at other times it may be present simply as a coating on the other mineral fragments found in the clay. Or it may also be present as a con-

stituent element of other minerals and be set free from them in the weathering of the product. When the iron weathers out it forms limonite or iron rust, and many fire-clays are often exposed to the weather, partly for the purpose of rusting out and bringing to light the spots of iron which they contain. In addition to being an important fluxing material in clay, it is also the coloring agent of many clays in both their raw and their burned condition. The effect which iron produces is dependent partly on the quantity present and partly on the condition of its combination, that is, whether it is combined with silica, carbonic acid, or some other acid.

SIDERITE.

The composition of this mineral is carbonate of iron. It may occur in many clays but is not usually noticed and has seldom been identified, although it is highly probable that it is present when the clay contains both considerable iron and carbonic acid. It sometimes occurs in a very prominent form, however, when it gives rise to concretions. These are not especially abundant in the unconsolidated clays of the Coastal Plain formations.

There is one member of the Potomac group, however, the Arundel, in which carbonate of iron is extremely abundant, in fact many of the Arundel clays contain such a large quantity of these concretions that the deposits are spoken of as ore-banks and the clays in many cases have been worked over on an almost gigantic scale for the purpose of extracting these nodules of iron carbonate. They have in cases been changed superficially to limonite. In many points around Baltimore and southward in the vicinity of Hanover, and Soper Hall, there are to be seen great banks of the bluish plastic clay which represent material thrown out or dug over in the mining of the siderite (white ore) nodules. These dump heaps now often serve as the basis of great local developments of the brick-making industry, the clay forming a structural brick of most excellent quality.

In the Carboniferous shales of Allegany and Garrett counties they are often met with. In such cases these concretions, which may vary in diameter from a few inches to one or two feet, are

usually round in outline, but rather flat and occur parallel with the bedding.

GYPSUM.

Gypsum may be present in the clay in the form of grains, needles, well-formed crystals, or lamellar masses. When in grains sufficiently large to be seen by the naked eye its characteristics are well marked and can be easily determined. It is very much softer than calcite, so soft, indeed, that it can be scratched easily by the finger-nail. The mineral is transparent and muriatic or other acid when put upon it causes no effervescence. Gypsum may sometimes be an original mineral in the clay or it may be formed by the action of pyrite on carbonate of lime. In none of the Maryland clays which have been examined by the writer have any large grains of gypsum been noticed, although it is probable that it exists in the material at times in the form of very fine grains.

The effect of gypsum on clay is that of a flux, especially if the brick is burned to vitrification, but if the clay is not burned sufficiently hard to drive off the sulphuric acid which the gypsum contains combined with the lime, then soluble sulphates may be left in the clay, which will be brought to the surface of the brick where they cause an unsightly white coating upon evaporation of the moisture.

Mr. Arthur Bibbins, who has done much work on the stratigraphy of the Potomac group, informs me that gypsum crystals are found in some of the Maryland clays at Muirkirk, where the gypsum grains form druses on the ore; also in the Arundel clays of the Spring Gardens district, the Patapsco clays which form the lower portion of the section at Fort Washington, and in the Miocene clays at Rosecroft, on the St. Mary's river. At this last-mentioned locality the crystals sometimes form aggregates weighing as much as ten pounds.

PYRITE.

This mineral is a sulphide of iron which usually occurs in small grains, but sometimes in lumps. It has a metallic lustre and yellow color, and is found very frequently in fire-clays and not uncommonly

in some of the black clays containing considerable carbonaceous matter. When it occurs in the form of concretions the popular name for them is "sulphur balls." When in the form of these large concretionary masses, which sometimes may be two or three inches in diameter, the pyrite can easily be removed either by picking out during the digging of the clay or separating by washing. At a number of points in the Coastal Plain clay deposits pyrite is found associated with lignite and not uncommonly the sulphide of iron, or pyrite, seems to have been deposited around sticks or lumps of lignite in the clay. Anyone going along the shore of Chesapeake Bay from Bodkin Point southward can pick up dozens of specimens of this nature which have been washed out of some of the clay deposits found in that region. It is not, of course, found in all of the clay beds. When in the form of finely divided grains the pyrite is naturally very difficult to remove. In fact, it is almost impossible except by means which are more expensive than operations would warrant. In the burning of clay pyrite will be changed to sulphate of iron, which is soluble. If the clay be heated any higher than to bring about this change, then the sulphate of iron may be brought to the surface of the finished brick by evaporating moisture and cause a discoloration. If, on the other hand, the clay is heated to vitrification the pyrite will serve as a flux, each grain of pyrite giving rise to a small fused spot of a ferrous silicate of complex composition. The speckled Pompeiian products so much used by architects of the present day were formerly made up by mixing specks of pyrite with the clay, but at the present time the use of pyrite has been superseded by the use of manganese.

DOLOMITE.

The double carbonate of lime and magnesia, dolomite, and magnesite, the carbonate of magnesia, may both occur free in clay as earthy grains or as rhombohedral crystals. Either of these when taken alone is highly refractory, but when found in clay their action is that of a flux. Dolomitic grains would perhaps be mostly looked for in those clays which are derived from the decomposition of dolomitic limestones.

GARNET.

In some deposits of kaolin may be found bunches of biotite mica and also grains of garnet, this latter on exposure rusting and forming ferruginous spots in the clay. Such spots are commonly avoided in mining, or the grains may be eliminated in the washing process. Aside from this occurrence, garnet is also at times found in sedimentary clays, although its presence is not usually very noticeable and is only detected when the clay is examined microscopically. It would act as a flux and melts at a comparatively low temperature, as low as cone 3 or 4.

HORNBLENDE.

This is not an uncommon constituent of many ferruginous clays and when present is generally in the form of tiny scales or flakes of a dark green color, showing transparency under the microscope only when extremely thin. Pyroxene may also be present and may be similar to the hornblende. It is highly probable that neither of these minerals remain in the clay very long in the fresh condition, for both decompose readily, yielding hydrated ferric oxide or limonite.

ALUM.

In many clays and shales the weathered surface is often covered by a slight coating which on closer examination is seen to be composed of tiny, needle-like crystals. Such coatings are very likely to be found in clays or shales containing pyrite, and are known as alum. It results from the action of the sulphuric acid, set free in the decomposition of the pyrite, on the alumina of the shale, forming a sulphate of alumina or alum. Gypsum may in some cases form a similar coating, but the alum can easily be distinguished by its bitter taste. Some clays contain this substance in a finely divided condition, and therefore do not always show the crystals on the surface. Alum is a material which no doubt occurs in many clays, but its effect has seldom been considered. In the underburned brick it might act the same as gypsum, namely, be soluble, in which case the sulphate would be brought to the surface in moist weather and left there in the form of coating. If the clay were heated high enough to dis-

sociate the compound then the sulphuric acid would be given off and the alumina left behind.

RUTILE.

This is probably much more abundant in clays than is usually supposed. Its common form is that of small needle-like crystals, too small to be seen by the naked eye and only detected under the microscope. The systematic study of the grains in clays has never been taken up, but judging from the percentage of titanium, which varies from a few tenths to 2 or 3 per cent, often found in fire-clay, there no doubt is a common occurrence of rutile in that material.

VIVIANITE.

This mineral, which in composition is a phosphate of iron, has, so far as the writer is aware, never been described as a common constituent of clay. Indeed it is probably not. At one locality, however, on the shore of Chesapeake Bay some distance south of Bodkin Point, there is a large exposure of plastic clay which is liberally dotted with small blue spots of vivianite. In the burning of the clay the phosphoric acid probably passes off when a sufficiently high temperature is attained, leaving the iron oxide behind, which simply acts as a coloring and fluxing agent. It is barely possible that the vivianite may perhaps exert some influence on the absorptive power of the clay for water, for the reason that a sample of this material which was tested showed a very high water capacity. The clay burned to a deep red color, and did not otherwise seem to indicate that the presence of the phosphate had produced a marked effect on its other characteristics. (See sample 266, described under the Pleistocene clays.)

MAGNETITE.

This is a magnetic oxide of iron and there is no doubt that it is found in many ferruginous clays in the form of very small grains, although it probably weathers rather rapidly to limonite. It is seldom noticed, but when present would serve to act as a fluxing material.

ORGANIC REMAINS.

These consist of bituminous matter, roots, amber, and other substances which volatilize on ignition. Since much of the organic

matter found in clays is no doubt more or less colloidal in its nature, it doubtless may greatly increase the absorptive power of the clay several per cent. The organic matter usually present is either in the form of leaf and stem fragments (fossil) or else in a more finely divided condition, so finely distributed through the clay as to give it a uniform dark gray or black color. In addition to increasing the absorptive power of clay, it may perhaps have some effect on its plasticity. The manner in which it makes its presence most felt, however, is in the burning, during which portions may exert important reducing influences and also increase the porosity of the burned ware provided it is not heated above a certain point. These effects, however, are more fully discussed under the properties of clay.

Properties of Clays.

TEXTURE.

Clays vary considerably in their texture, from those which are so fine-grained that no grit is detectable between the teeth to those which show coarse grains so large that the particles of sand scattered through them are plainly visible to the naked eye. For practical purposes it is perhaps of sufficient importance to determine the amount of any common clay which will pass through a sieve of 150 meshes to the inch and the quantity of the same material which remains on the sieve, since in the preparation of clays for the market by the washing process they are seldom required to pass through a screen any finer than that above mentioned. A more accurate method of determining the texture of a clay would be that commonly applied in the case of soils. In such a method, which is known as a mechanical analysis, the sizes of the grains recognized by this process, together with their names, are as follows:

Diam. of grains in mm.	Conventional name.
2 — 1	Gravel
1 — .5	Coarse sand
.5 — .25	Medium sand
.25 — .1	Fine sand
.1 — .05	Very fine sand
.05 — .01	Silt
.01 — .005	Fine silt
.005 — .0001	Clay

The usual method of making a mechanical analysis of the soils has been to subject the disintegrated soil or clay to the upward current of water at a known velocity. This is usually carried out in some form of apparatus consisting chiefly of a long tube into which the water enters at the lower end and overflows at the upper end, it being possible to regulate the velocity of the current. If the clay sample be placed in such an apparatus and the water allowed to pass through it at a very low speed, then only the smallest particles will be carried off. This is usually kept up until the water is clear and then the velocity of the current is increased sufficiently to carry off particles of about the size of fine silt; an additional increase will take off the grains or the next size to be separated. While this method has been in use for a number of years in both Europe and this country, at the same time it has been open to certain objections. More recently the U. S. Department of Agriculture has devised a machine known as the centrifugal apparatus, which yields results fully as accurate, if not more so, than were obtained by the old method, and it also requires a much smaller amount of water for the operation. The apparatus used in the centrifugal method as described in Bulletin 64, of the Department of Agriculture, consists of a "Holtz-Cabot 110-volt, 16-inch fan motor to supply the power for rotating the centrifugal apparatus. The motor uses a current a little in excess of that required for the ordinary 16-candle power lamp, and as constructed in its improved form will carry eight centrifugal tubes of the dimensions described below without serious heating. This style of motor is supplied with a rheostat in its base, enabling four different speeds to be obtained, which is a great advantage in making separations, besides enabling the motor to be gradually brought up to full speed. The rheostat is also provided with an open contact point for stopping the motor.

"The fan and fan guard being removed, the motor is firmly screwed to a rigid supporting frame with its armature shaft vertical. A second hollow shaft, milled to fit the armature shaft, is slipped over the latter and fastened by a set screw. To the lower end of the hollow shaft are fastened four horizontal arms, each being about 8

cm. long and consisting of two parallel bars of 5 mm. square brass, 4½ cm. apart. A brass ring 5 mm. thick is trunnioned between each pair of bars at their free ends, and four light brass rods extend downward from this ring to a similar ring 15 cm. below. This trunnioned system swings outward and upward in the well-known way when the motor gathers speed. It is important that the system should swing freely and care should be taken that the trunnion screws are sufficiently massive to stand the strain to which they are subjected at high velocities.

"Large heavy test tubes (18 by 3 cm.) serve admirably for the centrifugal tubes. The aperture in the upper metal ring is made large enough to admit the test tube easily, while the opening in the lower ring is somewhat smaller and provided with leather or cork washers on which the test tube rests. A guard consisting of a screen of 5 mm. mesh surrounds the movable portion of the apparatus as a safeguard against accidents. To protect the motor, the wires leading from the lighting current should contain fuses which will melt for currents exceeding two or three amperes.

"The analyses of four samples may readily be carried on at the same time. Ten grams constitute a suitable sample for analysis in an apparatus of the dimensions described. The preliminary preparation consists in agitating the sample of soil with about 200 cm. of water in a mechanical shaker[3] from six to eight hours, or until the surface of the larger grains, as seen under the microscope, appear to be clean and free from clay particles.

"A portion of the contents of each shaker bottle is transferred to its corresponding centrifugal tube. The apparatus is then rotated for a length of time sufficient to throw down from suspension all particles larger than those which it is desired to retain in the finest separation. The 'clay' water is then decanted into beakers and the remainder of the contents of the shaker bottles transferred to the tubes, the heavier material being thrown down as before. An important feature of the operation now claims consideration. In making additions of distilled water to the tube to effect further separations

[3] Whitney, Bulletin 4, Division of Soils, U. S. Dept. of Agri., 1895, p. 5.

of 'clay,' it is desirable and important that this water should be forced in under considerable pressure. This forms the most satisfactory and convenient means of getting the material at the bottom of the tube into suspension again, being far superior to any agitation with a stirring rod or a rubber pestle, since it avoids all abrasion and the necessity of washing off the stirring rod each time. It will be found that the stirring of the material in the bottom of the tube by the jet of distilled water each time a decantation is made will materially shorten the time and diminish the amount of water required for an analysis. The apparatus for securing this pressure will be referred to later.

"When the 'clay' has all been separated, as determined by a microscopic examination, using a micrometer, the tubes should be rotated for a shorter time, or at a lower rate of speed, leaving the particles constituting the next separation in suspension. The water containing these particles is then decanted into separate beakers and the process repeated until the separation of the second grade is effected.

"In making separations of particles exceeding 0.01 in diameter, the sedimentation is sufficiently rapid to avoid the necessity of using centrifugal force. The distilled water is, therefore, added by means of the jet, and the material in suspension allowed to subside for a suitable length of time, as in the beaker-method. Two separations, the clay (0.005 to 0.0001 mm.) and fine silt (0.01 to 0.005 mm.), are thus made by the use of centrifugal force. The silt (0.05 to 0.01 mm.) is separated by simple subsidence. The material remaining in the tube constitutes the sands, which are dried and separated by means of sieves and bolting cloth.

"The clay water does not usually exceed 600 cc., while the fine silt and silt together require about 500 cc. If these two last-named separations are allowed to stand for a day or more, they will, of course, settle to the bottom of the beakers, but the water in which they were suspended will be found somewhat turbid, indicating the presence of clay. No matter how carefully the separations may be made, this turbidity will nearly always occur, indicating a slight

disintegration of these separations into finer material. This turbid water may be added to the water containing the 'clay' in suspension if desired, although one will be justified in combining this suspended material with the sediment from which it was obtained. This latter method is preferable in soils containing large amounts of soluble material, such as the gypsum soils.

"If desired, the silt and fine silt sediments can be confined to very small volumes of water by again passing them through the centrifugal apparatus at a high velocity, which throws down all sediments, leaving the clear water which may be decanted. This sediment may then be washed with a small quantity of water into small platinum evaporating dishes. As recommended by Hopkins, it is highly desirable to evaporate the whole of the clay water, the volume being so small as to permit this being readily done. Porcelain dishes are suitable for evaporation of the liquid to a small volume, when it may be transferred to platinum dishes for ignition."

The determination of the texture of a clay may have a bearing in several different features. In the first place the plasticity of clay is undoubtedly influenced to a large extent by the fineness of grain of the material, those clays which contain a large amount of sand showing a rather low plasticity. The fineness of grain also affects the absorptive power of the clay, coarse-grained sandy clays absorbing very little, while fine-grained clays, especially if this fineness of grain is due to the large percentage of clay particles, often soak up very large quantities of water. One of the most remarkable examples of this is a material known as soap-clay from Albany county, Wyoming, which is composed of extremely fine particles of uniform size. This material has such a high attraction for water that when mixed with the latter it will soak up enough to increase in bulk almost eight times. Fineness of grain also seems to increase the tensile strength of the clay and likewise its shrinkage.

In the manufacture of the higher grades of clay products such as stoneware, whiteware, and encaustic tile, it is often necessary to employ materials of an even grain, and when this cannot be obtained in the natural condition they often have to be prepared by washing.

Hence the mechanical analysis may give us some valuable clues regarding the usefulness of the clays in this direction.

The Chemical Constituents of Clays and their Effects.

The custom has usually been to discuss this under the head of chemical properties of the clays, but this perhaps is somewhat incorrect for the reason that the different effects which are brought about by variation in the percentage of these chemical constituents are really physical ones.

The properties of the clay which are influenced by its chemical composition are its fusibility, the color in burning, the shrinkage in burning, and perhaps also its plasticity. Most clays show the following components: Silica, alumina, iron oxide, lime, magnesia, potash, soda, with titanic acid, sulphuric acid, manganese oxide, phosphoric acid and organic matter present in smaller amounts.

A detailed chemical search has even disclosed the presence of rare elements in the clay at times. What might be termed a pure clay or one made up entirely of kaolinite grains would contain simply silica, alumina, and combined water; but such a clay has, up to the present time, not been found, for even the purest ones known show trace of iron oxide, lime, the alkalies, and perhaps even other elements.

Nearly all of the constituents of clay may influence its fusibility, and those which are especially active in this direction are usually spoken of as fluxing impurities, the intensity of their action being at times very great.

On this account it is often customary to divide the materials found in clay as fluxing and non-fluxing impurities. While this is reasonable to a certain extent and perhaps also desirable, at the same time it is somewhat misleading for the reason that certain elements belong properly in both classes, an example of this being silica, which serves as a refractory element at lower temperatures while at very high temperatures it acts as a flux.

Pure clay, which is theoretically composed entirely of the kaolinite as above stated, is very refractory. This mineral contains two molecules of silica and one molecule of alumina together with

two of water. A higher percentage of silica tends, up to a certain point, to increase the fusibility provided it is in a finely divided condition. If the silica percentage, however, gets above a certain point, the refractoriness of the clay increases with the increase in silica up to the point at which the mass would contain nothing but silica. This has been shown by the experiments of Seger.[4]

The effect of fluxes in the clay is closely connected with the quantity of them which is present and also with their state of division, for the more evenly divided they are the more intense will their fluxing power be. This is easily understood if one considers the case of the fluxes being present in the form of large grains. When the clay is heated these grains will exert a fluxing action only on their surfaces, and the single grains will act more or less like quartz grains. If, on the other hand, the fluxes are in a very finely divided condition, the surfaces of the grains will naturally be much greater and the fusion can go on at a greater number of points at the same time. The quantity of fluxes stands in very close relation to the use or commercial value of the clay. Fire-clays which are called upon to resist a high degree of heat must have a very small percentage of fluxing materials in their composition, while common brick-clays which are used for the manufacture of cheap grades of bricks must have sufficient fluxes to make them burn dense at a low temperature. The fact that two clays contain the same percentage of fluxing materials does not necessarily indicate that they will both fuse at the same temperature, for the base in each of the two clays may be united with a different acid. Thus potash might be present in one clay in the form of carbonate and in another clay it might be found as an ingredient of some silicate mineral, such as mica. That containing the carbonate of potash would flux much more readily than that containing the silicate.

In clays which are to be used for the production of vitrified ware it is desirable to have a large quantity of fluxing materials, and in some cases it is even necessary to add these artificially.

[4] Thon Industrie Zeitung, 1893, No. 17.

ALKALINE FLUXES.

These include potash and soda, lithia being so rarely present that it need not be considered. All of the sources of these two fluxes are silicate minerals of usually complex composition. There are few clays which lack a certain quantity of feldspar and mica, especially the latter, and it is thus that very much of the potash and soda is usually derived, although other minerals containing them may also be present, such as garnet, hornblende and pyroxene. The last three are to be found more in the bright-red colored clays, especially those which are so abundant in places in the Piedmont region of Maryland. The residual peridotite clay, for example, which is dug four miles northeast of Catonsville and used in the manufacture of red flower-pots, is a good example of a clay derived from this type of rock.

The feldspars which are a good source of alkalies are complex silicates of alumina and potash, or alumina, lime and soda. The percentage which they contain varies from 4 per cent to 12 per cent, as in the lime-soda feldspar, up to 17 per cent in the potash feldspar, orthoclase. The former are more fusible and therefore more active fluxes than the latter.

The micas are complex silicates of alumina with iron, magnesia and potash. Muscovite, the commonest species of the group, contains nearly 12 per cent of potash and may contain a little soda. While the feldspar fused completely at 2300° Fahr., muscovite mica alone is quite refractory, being unaffected by the temperature of 2550° Fahr. But it begins to fuse very soon above this and melts easily to a glass at a temperature not above 2800° as determined by experiments made by the writer. The other common kinds of mica, such as lepidolite, phlogopite and biotite, are all much more fusible, the phlogopite being next to muscovite in refractoriness, then the lepidolite, and lastly the biotite, which melts down rather easily to a dark glass. The last-mentioned species of mica, however, does not play a very important rôle among the fluxing minerals of clay for the reason that it seldom remains in the clay in an unaltered condition, being one of the mica species which de-

composes very readily on exposure to the weather. One of the effects of this decomposition is to yield limonite or iron rust, to which is due the deep-red color of many of our residual clays found in the Coastal Plain region.

Alkalies, especially in the form of silicates, are frequently desirable constituents of clay on account of their fluxing properties, as in burning they serve to bind the particles together in a dense, hard body and permit the ware being burned at a lower temperature.

In making porcelain, white earthenware, encaustic tiles and other wares in which kaolin is used to a greater or less extent in the body, the alkalies are usually added for fluxing in the form of feldspar. Much feldspar is mined for this purpose both in the United States and Europe, but in the majority of cases it is the potash feldspar.

So far as is known, the alkalies exert little or no influence on the color of the burned ware, although a high excess of feldspar added to the white burning clay will tend to produce a creamy tint. The amount of alkalies contained in the clay may vary considerably, ranging all the way from a mere trace up to 7 or 8 per cent. The limits for a number of cases are given below:

	MINIMUM.	MAXIMUM.	AVERAGE.
Kaolins	.10	6.21	1.01
Fire-clays	.048	5.27	1.46
Pottery clays	.52	7.11	2.06
Brick clays	.17	15.32	2.768

Owing to the similarity in composition of muscovite to kaolinite, it is easily possible to have a kaolin contain 8 to 10 per cent of this mica and yet in the ultimate analysis appear to approach very closely to the composition of kaolinite. This difference should show up in the rational analysis of the clay provided the latter were thoroughly satisfactory. Up to the present time it has been customary to lump the white mica in as clay substance, in which case it would not be necessary to separate it from kaolinite. The wisdom of continuing this course, however, is still to be determined.

In addition to the alkalies already referred to, clays may contain a variable quantity of volatile alkali such as ammonia. This latter exerts no fluxing influence on the clay in burning for the reason that

it is driven off at a comparatively low temperature. It may, however, affect the physical properties of the clay in its green condition, for it is known that clays possess a strong absorptive capacity for gases and therefore often hold appreciable quantities of ammonia in their pores. It is possible that the ammonia, in serving to keep the clay grains puddled, thereby preventing their flocculation, may tend to increase the plasticity of the mass.

IRON OXIDE.

This material acts both as a flux and a coloring agent. The variegated tints of many of the clays seen in the Coastal Plain region of the State, and also those overlying the limestone formations in the Piedmont region, or around Hagerstown, are due entirely to the iron which the clay contains. This may give the clay a yellow-brown or red tint, or even bluish-gray, according to the compound which is present. Iron is not only one of the most widespread and common ingredients of clay, but it is also derived from a far greater number of minerals than any of the other elements found in this material. Thus iron is found in the form of oxide in the minerals limonite, hematite, magnetite and ilmenite; or combined with other elements in the form of the silicate as in mica, hornblende, garnet, etc.; in still other cases it is found in the form of a sulphide, as in the mineral pyrite; or of a sulphate, as in melanterite; finally, it frequently occurs as concretions made up of carbonate of iron or siderite. The "white ore" in the clay banks of the Arundel formation is of this character. In some of the Pleistocene clays of Maryland the iron is also found occurring as a phosphate which forms blue specks or lumps in the clay, and is known as vivianite. Whatever the original form of the iron in the clay, it will on being exposed to the weather slowly but steadily change to the mineral limonite, which is popularly known as iron rust. Furthermore, whatever the condition of the iron in the green clay, it will on burning in an oxidizing atmosphere be converted into the red oxide of iron, or hematite; or if the clay be carried up to the condition of vitrification or viscosity a complex silicate containing this oxide will be formed.

While the various iron compounds may exist in the clays as original constituents of the mass, at the same time they may also be introduced by the percolating waters filtering down through the soil. In such cases they are usually found more or less concentrated along the cracks or joints in the clay down which these surface waters have percolated.

Pyrite or the sulphide of iron is present in a great many clays, especially stoneware or fire-clays. Its yellow, glittering, metallic particles are easily recognizable. These particles may be either fine grains or large lumps of such a size that they can be separated easily by hand-picking in working the clay. Pyrite occurs in great abundance in the Pleistocene clays, for example, on Bodkin Point, where it is often found to have been deposited in and around fragments of lignite, which are also plentifully strewn through the clay bank, thus suggesting that the carbon of the lignite may have exerted a precipitating influence on the sulphide of iron which is found gathered around the material.

Pyrite alters under the influence of weather or fire to sulphate of iron, which is soluble in water and which may indirectly or directly act as a discoloration on clay wares, provided the ware is not burned to vitrification. If burned to this point, however, the pyrite acts as a flux, forming little specks or larger ones of fused ferrous aluminum silicate. When iron-bearing minerals are found in clays the iron exists in one of two conditions, namely, as the ferrous or ferric iron and the fusibility of any given clay may depend somewhat on this fact for the reason that ferrous compounds lower the fusing point of the clay. In the burning the ferrous salts will, however, be changed to the ferric condition unless the fire is reducing in its action. It is seldom necessary to be on the lookout for ferrous iron in clay, since the action of the weather will convert it into the ferric condition. This change usually proceeds from the surface downwards in the clay banks in which the iron has been thoroughly oxidized by the surface waters bringing oxygen to it and the lower portion of the bed in which the iron has not yet been changed. It should, however, be noticed that the gray color of clay is not always

due to the ferrous iron for the reason that organic or carbonaceous matter may cause the clay to assume a similar tint.

The rapidity with which the temperature of the clay is raised in burning is of considerable importance, for if the heat is raised too quickly the outer portion of the clay may shrink and become dense before the air has had time to permeate the clay and oxidize the iron of the interior of the brick or other bits of ware. This causes the presence of a black core in the center of the pieces of ware whose surface may be red. In any clay the depth of color produced by the iron will increase directly with the temperature at which it has been burned. The amount of ferric oxide which is permissible or desirable in the clay depends on the use to which it is to be put. Thus, kaolins or other clays to be used in the manufacture of white bodies should, if possible, contain less than one per cent. Brick-clays should have enough iron to give them a good red color, while in fire-clays the percentage should not exceed two or three per cent. The following gives the range of ferric oxide in a number of clays:

	MINIMUM.	MAXIMUM.	AVERAGE.
Brick clays	.126	32.12	5.311
Fire-clays	.01	7.24	1.506
Kaolins	trace	6.87	1.29

LIME.

Lime is a very common impurity of many clays, especially those which are of a low grade. As in the case of iron, it may be derived from a number of different minerals which belong to three general types, namely, silicates, carbonates or sulphates. The first would be represented by some feldspars, hornblende and garnet; the second by the minerals calcite or dolomite; and the third by the mineral gypsum. In those clays which have been derived from igneous rocks or gneisses the lime is likely to be present in the form of a silicate, while in many sedimentary clays such as those found in some portions of the Tertiary or Pleistocene of lower Maryland, or in those derived from the limestone, as around Hagerstown, the lime is usually present in the form of a carbonate. When gypsum is present in the clay it is likely to be of secondary origin. Lime

when present in a silicate acts as a flux, but is seldom likely to exert a decolorizing action on the clay except at high temperatures. Carbonate of lime may often be abundant in clays which have been derived from calcareous rocks or it may also result from the decomposition of lime-soda feldspars. The presence of carbonate of lime in a clay can usually be detected by putting a few drops of muriatic acid on the mineral.

The effect of the carbonate depends largely on its physical condition. In some clays it may be in the form of lumps or pebbles, which, unless removed by screening or washing before burning, may become very injurious. In other clays the lime is present in a very finely divided state and in such a condition seldom exerts a harmful influence, for clays with 20-25 per cent of carbonate of lime can be and are used for making common and pressed bricks as well as earthenware.

The action of carbonate of lime in burning a clay is somewhat as follows: when the temperature of the clay reaches redness the lime carbonate is broken up into CO_2 and caustic lime, the former going off as a gas. If the clay is not raised to the temperature of vitrification in order to make the lime unite by fusion with other ingredients, the former will, on cooling, absorb moisture from the air and slake and the swelling which this causes may be sufficient to cause a bursting or flaking off of the brick. Another effect of lime is that it tends to destroy the red color produced by iron, giving instead a buff or greenish product, depending on the amount of lime and the intensity of firing. In order to destroy the iron color it is necessary that the clay should contain at least three times as much lime as iron. In this connection it should be remembered, however, that the buff color of a burnt brick is not always due to the excess of lime, for the absence of lime, coupled with a low percentage of iron, may bring about the same effect in firing. In high-grade clays large amounts of lime ought not to be considered, for the use of such materials is out of the question. In the manufacture of building brick, pressed brick, or terra cotta it is sometimes necessary to use calcareous clays partly because no others can be obtained. With this clay a vitrified

ware can seldom be made for the reason that the points of incipient fusion and vitrification lie so close together that it is almost impossible in burning to reach the second without passing it and running into the temperature of viscosity. This trouble may sometimes be overcome by adding quartz and feldspar to the clay.

A third important effect of lime is the influence which it exerts on the shrinkage of the material for yellow calcareous or marly clays not only require less water as a rule to temper them but in burning they also shrink much less. Indeed, at the temperatures obtained in brick clays the shrinkage of the calcareous clay may not only be very low, but the product may be exceedingly porous, due to the escape of the carbon dioxide.

Gypsum, the hydrated sulphate of lime, is often found in clay, sometimes forming large transparent plates with a pearly lustre which are so soft that they can easily be scratched with the finger-nail; at other times being scattered through the clay in a finely divided condition. Gypsum may serve as a flux, but it at the same time may in burning do considerable damage by the liberation of sulphuric acid which will at times cause blisters on the surface of the ware. There are, however, but few clays in Maryland which contain sufficient gypsum to produce this unfortunate result.

All clays do not contain much lime and, in fact, it seems to be almost wanting in some, while in others it is present in great amounts. Thus most of the Potomac clays of Maryland are very free from it, while in the Tertiary beds along the lower Chesapeake Bay it is often found in great quantities. The range of lime in different clays is as follows:

	MINIMUM.	MAXIMUM.	AVERAGE.
Brick clay	.024	23.20	2.017
Pottery clay	.011	9.90	1.098
Fire-clay..................	.03	15.27	.655
Kaolin....................	trace	2.58	.47

MAGNESIA.

It rarely happens that magnesia is found in clays in large quantities, and in the case of the Maryland clays no instance of high magnesia content is known. It may be derived from the same classes of

compounds as lime. In those clays which contain large quantities of chloritic mica, which is often green in color and forms tiny, shiny scales, the magnesia may be high but these are rare. Hornblende may also furnish it, so that it might be looked for in the residual clays derived from the basic or dark-colored igneous rocks of the Piedmont region. Or again, it might be found in the residual clays derived from the Cockeysville marble belt, since this marble is of the dolomitic nature. Magnesium sulphate, or Epsom salts, occurs in clays, and when present may give rise to a white coating on the surface of the ware. The presence of this salt may be detected frequently by the bitter taste which it imparts to the clay. It should, however, be remembered that alum may also form a white coating on the surface of rocks and clays. So far as is known the chemical effects of magnesium in clay are similar to those produced by lime, and yet this effect is not absolutely established for the reason that magnesia is usually present in such small amounts that its exact effect cannot be told. This latter statement is well illustrated by the following percentages of magnesia in different clays.

	MINIMUM.	MAXIMUM.	AVERAGE.
Brick clays	.02	11.03	2.66
Pottery clays	.05	4.80	.85
Fire-clays	.02	6.25	.513
Kaolins	trace	2.42	.223

SILICA.

Three types of silica may be recognized in clay; namely, (a) quartz, (b) that which is combined with alumina and water in kaolinite, and (c) that which is combined with one or more bases in silicate minerals. In the usual chemical analysis the first and third are often placed together under the heading of sand or at times incorrectly as free silica. The silica included under the term *sand* is practically insoluble in sulphuric acid and caustic soda. This fact is utilized, as mentioned further on, in the rational analysis of clay to extract the kaolinite or clay substance, which is decomposed by sulphuric acid and soluble in caustic soda. So far as is known there are practically no clays which are actually free from quartz, although the percentage at times may be very small. It

has been found to range from quantities as low as .2 per cent up to as much as 50 per cent, while the sand percentage may range from 5 per cent up to as much as 70 per cent. The following table gives the variation:

	MINIMUM.	MAXIMUM.	AVERAGE.
Brick clays	34.35	90.877	59.27
Pottery clays	45.06	86.98	45.83
Fire-clays	34.40	96.79	54.304
Kaolins	32.44	81.18	55.44

Quartz serves as a flux only at high temperatures, above 2800° Fahr., but at lower temperatures it helps to increase the refractoriness and this is influenced somewhat by the size of the quartz grains, and the amount of the fluxing material present which will fuse at a lower temperature. It is therefore undesirable in adjusting a fire-clay to take one which is very sandy, especially if in use it is to be exposed to high temperatures. This means, of course, a fire-clay to be used for the very best grade of fire-brick or for glass-furnace blocks. In the case of stove-linings, which are never exposed to a very high heat, the effect of sand flux does not have to be considered.

TITANIUM.

Titanium occurs in the clay in the form of little nodules of rutile or oxide of titanium, and a microscopic examination of a number of samples almost invariably shows their presence if only in small quantities. Sometimes the mineral ilmenite, which is the titanium-bearing oxide of iron, may also be present. Since the titanium is present in such small quantities, in fact seldom exceeding 1½ per cent, or even less, it is not necessary to consider its effect. It may, however, be mentioned in passing that if it were present to the extent of six or seven per cent, it would serve as an active flux and tend to give the clay a bluish tint.

ORGANIC MATTER.

Organic matter affects not only the color of the clay, but also probably its plasticity and its absorptive power as well as its tensile strength. It is usually present in the clay in the form of finely divided plant-tissue or larger portions of plants or leaves which settled

in the clay during its deposition. An excellent example of the former may be seen in the dark brownish-black clay occurring in Swan Cove on the Magothy river. All surface clays contain plant remains in their outer layers, but these do not directly influence the color of the material. Clays which are colored by organic matter containing any iron will burn to a white tint since the plant-tissue burns off at redness; if such a clay, however, be heated too quickly before all the organic matter has been burned off from the interior surfaces, the heat becomes too intense and the section remains dark-colored, in case the organic matter should not escape in the burning. Organic matter may also tend to mask the presence of iron so that the black clay instead of burning white may burn red at a temperature above that at which the organic matter passes off.

In most chemical analyses the organic matter is seldom determined separately, but the amount of it can sometimes be judged from the ratio between the loss on ignition and the amount of alumina in the clay.

Water in Clay.

All clays contain two kinds of water:

1. Hygroscopic water, or moisture.
2. Chemically combined water.

Moisture.—Clays contain two kinds of moisture: 1. That which adheres to the surface of each clay grain as a thin film. 2. That which is held in the pores of the clay by capillary attraction. The former is of little importance practically. The latter is of importance in connection with the shrinkage and plasticity of clays. The amount of total moisture contained in clays varies within wide limits. In some air-dried clays it may be as low as .5 per cent, while in those freshly taken from the bank it may reach 30 per cent, or even 40 per cent. Capillary moisture is absorbed by clays only when they are brought into actual contact with water, but that which forms a film on the surface of the clay particles is readily absorbed by the clay from the atmosphere and to a certain extent given off again as readily, so that some days a brick if left exposed to the air would weigh more than on others. The amount of either kind of

moisture present in a clay depends on the number and size of the spaces between the clay grains, the size of the clay particles, and the amount of organic matter present.

Air-drying usually causes the evaporation of most of the water in a clay accompanied by a shrinkage of the mass, which ceases, however, before all the moisture has passed off. The reason for this is that the shrinkage of the clay ceases when the particles come in contact, which may happen and still leave interstices. These, of course, still contain moisture, and consequently the brick will keep on losing weight till not only this interstitial water, but also the surface moisture of the particles, is driven off. In practice, it is this that evaporates during the first period of the burning known as "water-smoking." The shrinkage of the clay attendant on drying varies with the nature of the material from 2 or 3 per cent to even 10 or 15 per cent. It is governed largely by the causes influencing the absorption of the clay.

Sandy clays usually show the least shrinkage, and of this kind the coarser grained diminish in size the least. Highly plastic clays generally show the highest shrinkage.

The amount of water which a dry clay needs in order to develop its maximum plasticity is a variable quantity. Plastic clays absorb large quantities of water, but a lean clay, if fine-grained, may do the same. As a very general rule, it may be stated that lean clays absorb from 12 to 20 per cent, while fat clays require anywhere from 25 to 50 per cent; and the more water a clay absorbs, the more it has to part with in drying and the greater will be its shrinkage.

Highly aluminous clays do not always absorb the most water, nor are they the most plastic. Some clays low in alumina and high in organic matter are not only highly plastic but also absorb a high amount of water.

Owing to the high shrinkage of most clays with high absorptive power, there is frequently danger of their cracking, if rapidly dried, on account of the active disengagement of water vapor.

Moisture may play another important and injurious rôle in the working of a clay, in that it tends to dissolve soluble salts in the clay,

and bring them to the surface in drying, giving rise to the formation of efflorescence. It may also permit acids contained in the fire gases of the kiln to act on the mineral ingredients of the clay and thus form soluble compounds, specially sulphates and chlorides.

By the addition of water to an air-dried clay, it gradually passes from a powdery or lumpy condition to a pasty mass, the tenacity of which increases till the point of maximum plasticity for the given clay is reached. If the addition of water be continued the clay gradually passes into a soft mud. In some clays this change takes place slowly, in others (especially many residual clays) very rapidly.

Combined water is present in every clay. In pure kaolin there is nearly 14 per cent, and amounts are found in different clays intermediate between this and 3 or 4 per cent.

The sources of combined water in clays are either kaolinite, limonite, or hydrated silicates; the quantity in different clays can be seen from the table of analyses given at the end of the report. It is driven off at a low red heat, and when this occurs an additional shrinkage takes place, the extent depending on the quantity of water present. The shrinkage varies commonly from 2 to 10 per cent, and reaches even 14 per cent.

While the amount of combined water does not seem to stand in direct relation to the plasticity of the clay, nevertheless, when it is once driven off, the clay can no longer be rendered plastic.

Color.

Clays vary considerably in their color, the purest ones being white in both burned and raw condition, while many others in their green or unburned state may show shades of red, yellow, brown, green, gray and black. The commonest colors are white, gray, and red or yellow. The gray and black colors seen in clay are commonly due to the presence of organic or carbonaceous matter in varying proportions. In some cases, however, gray may possibly be caused by the presence of ferrous carbonate. Limonite produces a yellow or brown color and hematite will often color the clay red in its green condition. Clays which are white or yellowish-white contain very little carbonaceous matter and also little or no iron. There

is often difference in the color of the clay, or rather in the shades, in the wet and dry condition, the tints being usually much brighter when the clay is moist than when it is dry. The color of burned clays is due almost invariably to the iron oxide which they contain and varies in both the amount of iron in them and also with the conditions under which they were burned, as will be explained later under the burning of clays.

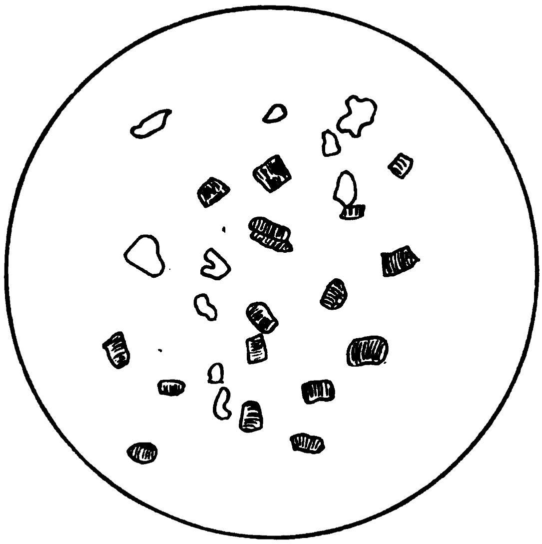


FIG. 5.—Microscopic section showing clay particles in ball-clay from Edgar, Fla.

PLASTICITY.

By plasticity is meant the property which the clay possesses of permitting itself to be molded into any desired form when wet and retaining this shape when dry. The exact cause of plasticity is one which has not yet been definitely determined, but probably depends upon the fineness of grains, the relative number of grains of different sizes, and probably also on the presence of grains of colloidal matter. One fact seems to be fairly certain and that is that the property of plasticity depends more on the physical condition of the clay than its chemical composition, for two clays which may closely resemble each other in chemical composition may differ widely in their degree

of plasticity. Most kaolins in their washed condition contain a high percentage of clay substance, and yet they are seldom very plastic. When analyzed their composition approaches closely to that of kaolinite. If, however, a sedimentary clay of considerable purity which closely resembles kaolin in its composition is taken it is found to be quite plastic. For this purpose a comparison may be made of the white, washed kaolin which is mined at Dillsboro, North Carolina, with the white, plastic, ball-clay from Edgar, Florida. The former is a residual clay found where it was formed while the latter is a sedimentary clay which has been washed down to its present resting place. In transit the particles have been ground apart either by rubbing against each other or by being crushed between the wet quartz pebbles which are so abundant in this deposit. If the Dillsboro clay is examined under the microscope it will show a number of angular fragments. If, however, the Florida one be examined it is found that the particles are quite different in their appearance, being scaly, often flat, and not infrequently collected in bunches. The similarity in composition of the two clays is well brought out by the following analyses:

	EDGAR, FLA.	DILLSBORO, N. C.
Silica	45.39	43.90
Alumina	39.13	40.66
Ferric oxide...........	.45	.14
Lime	.50	0.00
Magnesia	.29	trace
Alkalies	.83	.46
Water	14.01	14.84
	100.60	100.00

This shows quite plainly that the chemical composition is not an important cause of plasticity, and, in fact, may have nothing to do with it. It was at one time considered by many, and indeed is still held by some (although there is no ground for so doing), that plasticity is directly connected with the hydrated silicate of alumina, or kaolinite, and clays which were rich in kaolinite were supposed to be highly plastic. As a matter of fact, however, clays which contain a high percentage of kaolinite are usually lean, while some of the most plastic known are very low in kaolinite; and yet the mineral

kaolinite may exert some influence. Professor G. H. Cook[5] advanced the theory that plasticity was due to plate structure in the clay. That is, if one take two plates of glass or mica, with smooth flat surfaces, moisten them and then press the two together, it will be found that considerable force is required to pull them apart. They will, however, glide over each other very easily. Professor Cook supposed that if the clay were made up to a greater or less

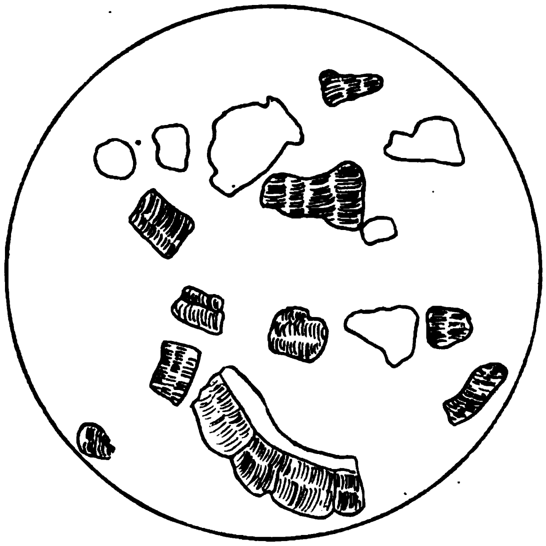


Fig. 6.—Microscopic section showing fine silt particles in ball-clay from Edgar, Fla.

extent of such plates, but of extremely small size, then they will slide over and past each other in different directions and give mobility to the mass.

He found on microscopic examination that many clays contained little bunches of these plates, and that if these were broken up and the plates separated so that they could move freely the plasticity of the clay would be increased.

Fig. 5 shows a microscopic enlargement of the clay particles in a plastic ball-clay from Florida and Fig. 6 shows the fine silt particles of the same clay. It will be noticed that both contain single and bunched plates of kaolinite.

[5] N. J. Geol. Survey, 1878. Clays of New Jersey.

If, however, an exceedingly plastic clay is examined under the microscope, it is found that in addition to the regular particles of a scaly nature, there may be a large number of extremely minute, spherical, structureless particles, which may be in the nature of colloids. If a mixture of the plates and these spherical particles is considered, it appears that they might yield a mixture of high mobility and cohesiveness, the rounded particles filling the interstices between the plates.

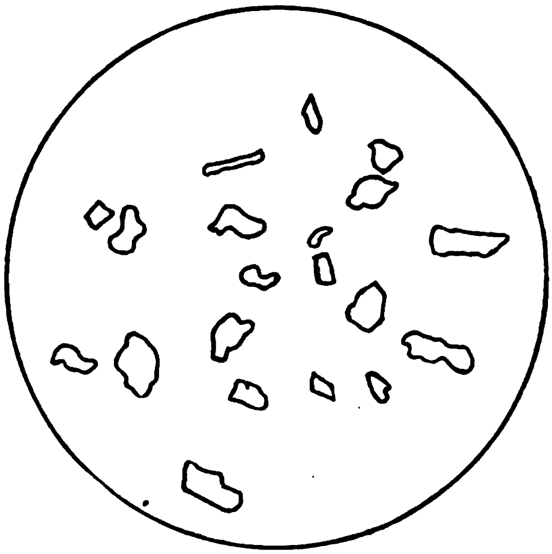


FIG 7.—Microscopic section showing uneven surfaces of clay particles.

Again, if one take a mixture of sand grains, even though they are very small, it will not show plasticity. The material may absorb water, as should be expected of a finely divided material, but it is not plastic and mobile. The reason for this is simple. The sand grains are neither plate-like nor do they possess flat surfaces, which would permit them when wet to cohere as a result of surface tension, or to glide over each other. Moreover, if a mechanical analysis of a clay of moderate plasticity is made it is found that there are not only very few small spherical particles and plates, but that the grains present uneven surfaces, which would resist cohesion and gliding. Fig. 7 shows this. In Fig. 8 are some particles of a lean kaolin.

Both an increase in the size of grains and the presence of much mica, except when of the smallest size, interfere with plasticity.

Various methods have been tried for measuring the plasticity of clay, but most of them are unsatisfactory, partly for the reason that they depend to a large extent on the personal equation of the experimenter. The most usual method is to measure the tensile strength, it being considered by many that this stands in direct relation to the plasticity.

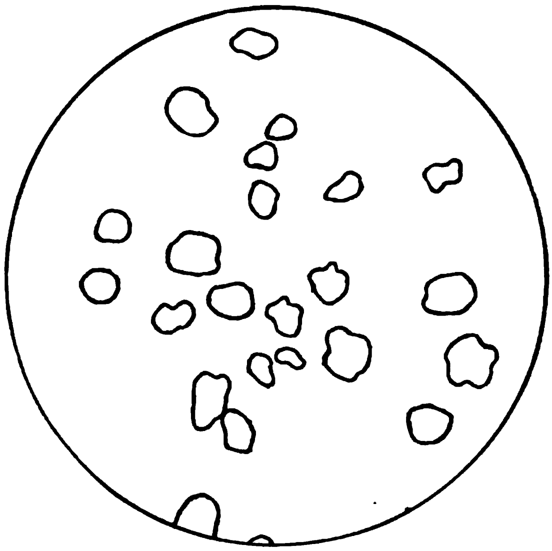


FIG. 8.—Microscopic section showing particles in in a lean clay.

Most clays of high plasticity also show a high tensile strength, but, on the other hand, many which are quite plastic to the feel have only moderate cohesiveness when dry.

The amount of water required to develop the maximum plasticity of a clay varies, highly plastic ones requiring the most water.

FUSIBILITY.

The softening of clay under the action of heat is not a sudden change, but may extend over a range of several hundred degrees before the material becomes viscous.

Some clays fuse more rapidly than others, and the temperature

at which softening begins depends on the percentage of fluxing impurities which the clay contains, those clays being most refractory which have the lowest quantity of fluxes.

In heating a clay in the kiln or furnace it not only begins to shrink, but also to harden. One of the first changes occurring after all the moisture has been driven off is the oxidation of the iron, any ferrous compounds present being changed to the ferric form. The clay at this stage is still soft enough to be scratched with a knife. Further heating, after redness has been reached, causes the clay to lose its combined water and shrink an additional amount, becoming not only harder but denser, until it becomes non-porous. Its hardness when burned to this condition would be about 6 in Moh's scale,[6] or that of feldspar.

The beginning of fusion is usually indicated by the clay reaching a hardness equal to that of six. In many clays which have been burned to this condition the clay particles are commonly still recognizable. If the temperature be raised above this point from 50 to 200 deg. Fahr., or sometimes even more, an additional amount of shrinkage occurs, and during this additional rise in the temperature many or all of the particles of the clay become sufficiently soft to settle together into a dense condition, leaving practically no spaces between the grains. This condition is spoken of as vitrification and clay products are said to be vitrified or completely sintered when the particles can no longer be detected and the maximum shrinkage has been reached. With a still further rise in temperature the clay becomes viscous. Three stages, therefore, may be recognized in the burning of clay: incipient fusion, vitrification, viscosity.[7] These three stages are not by any means sharply defined; in fact, it is sometimes difficult to say just when incipient fusion has begun. It is, however, not at all difficult to see that some clays soften much

[6] Moh's scale refers to a series of 10 minerals, of which talc, the softest, is No. 1 in the scale, while diamond, the hardest, is No. 10. The intermediate ones are: 2, gypsum; 3, calcite; 4, fluorite; 5, apatite; 6, feldspar; 7, quartz; 8, beryl; 9, corundum.

[7] These three terms have been suggested by H. A. Wheeler. Vitrified Paving Brick, p. 12, 1895.

more rapidly than others. The difference in temperature between incipient fusion and the viscosity varies with the composition of the clay. In calcareous clays these two points may be within 50 or 60 degrees of each other, while in refractory clays they may be separated by an interval of 600 to 700 degrees. The glass-pot clays approach most nearly to this latter condition. Very many clays show a difference of 400 and 500 degrees between points of incipient fusion and viscosity.

This has a practical bearing, as can be easily understood when one recognizes the fact that in the manufacture of many kinds of clay products the body has to be vitrified, and that it is not always possible to stop the burning of a kiln within the range of a few degrees. It is, therefore, readily understood that the greater the difference between the temperature of vitrification and that of viscosity the easier will it be to burn a kiln of a ware up to the one point without being in danger of immediately running into the other by slightly overstepping the first.

The fusibility of a clay may depend on the amount of fluxes, the size of the grain of the refractory and non-refractory constituents, or the condition of the fire, whether oxidizing or reducing. Other things being equal, the greater the percentage of the fluxes the lower the fusing point of a clay. This point can be well illustrated by the following figures, which give the total percentage of fluxes of several clays, together with their points of fusion:

CLAY.	TOTAL FLUXES.	TEMP. OF VISCOSITY.
Albany slip	18.47	Cone 01
Marlboro red clay	4.60	" 10.
Raritan clay, Severn river	3.02	" 30

Fine-grained clays will fuse at lower temperatures than coarse-grained ones, other things being equal. This is quite readily understood when the fact is considered that the fusion of the particle begins at the surface and extends inward towards the center. If, therefore, one have two clays containing given quantities of feldspar, the grains in the one case being as fine as clay particles, the grains in the second case being the size of silt particles, it is easily seen that if the two clay samples are heated to the same temperature the

FIG. 1.—WORKING A CLAY DEPOSIT AS AN OPEN PIT.

The Friedenwald Co.

FIG. 2.—ENTRANCE TO FIRE-CLAY MINE ON SAVAGE MOUNTAIN.

fine particles of feldspar will fuse much sooner than the coarse ones, and that the latter fusing more slowly will tend to serve as a stiffening medium or skeleton in the clay and to aid it in retaining its shape for a longer period. This is a fact which the writer has found to be the case by actual experiment. Samples of kaolin were taken and mixed with grains of feldspar, the grains in one case being equal in size to clay particles, those in the second case being equal in diameter to fine silt particles. The two were heated to a temperature considerably above the fusing point of feldspar and after doing so it was found on sectioning the test pieces and examining them under the microscope that the mixture of clay and fine feldspar particles represented a thoroughly fused mass, whereas the mixture of clay and coarser feldspar particles showed many grains of but partially fused feldspar scattered through the body. This would be in direct contradiction to the statement made by Hofman, who claims that the size of the particles does not affect the fusibility of the clay.[8]

DETERMINATION OF FUSIBILITY.

The temperature at which a clay fuses may be determined in several different ways. One method is to use some form of apparatus, or mechanical pyrometer. Another is to use test pieces. A series of test pieces which is widely used by practical clay-workers is that known as the Seger cones, which consist of a series of mixtures of clay with fluxes so graded that they represent a series of fusing points, each being but a few degrees higher than the one next below it. The materials used in making them are such as would have a constant composition and are: Zettlitz kaolin, Rörstrand feldspar, Norwegian quartz, Carrara marble, and pure ferric oxide. Cone 1 melts at same temperature as an alloy composed of one part of platinum and nine parts of gold or at 1100 degrees Centigrade. Cone 20 melts at the highest temperature obtained in a porcelain furnace or at 1530° C. The difference between any two successive numbers is 20 degrees. The upper member of the series is cone 36, which is composed of a very refractory clay slate, while cone 35 is composed of Zettlitz kaolin.

[8] Trans. Amer. Inst. Min. Eng., vol. xxviii., p. 440.

A lower series of numbers was produced by Cramer, who mixed with boracic acid the materials already mentioned. Hecht obtained still more fusible ones by adding both boracic acid and lead to the cones. The result is that we have now a series of 58 numbers, the fusion of the lowest being 710° C., and that of the highest 1850° C.

As the cone reaches its fusion point, it begins to bend over, and it is considered that the kiln has reached the fusion temperature when the tip bends over so as to touch the base.

FIG. 9.—Seger cones before and after testing.

For practical purposes these cones are very successful, though their use has been perhaps somewhat unreasonably discouraged by some. The full series can be obtained from Messrs. Seger and Cramer, of Berlin, for one cent each (or about two and one-half cents each, including duty and expressage), or Nos. .010-10 can be obtained for one cent each from Professor Edward Orton, Jr., of Ohio State University, Columbus, Ohio. The table of the cones with the fusing points and composition are given herewith.

FUSION TEMPERATURES BASED UPON RECENT RECALCULATIONS FOR SEGER'S PYRAMIDS.

No. of Cone.	Composition.						Fusion Point. Cent.	Fusion Point. Fahr.
022	0.5 0.5	Na_2O PbO	....		2 1	SiO_2 B_2O_3	590	1094
021	0.5 0.5	Na_2O PbO	0.1	Al_2O_3	2.2 1	SiO_2 B_2O_3	620	1148
020	0.5 0.5	Na_2O PbO	0.2	Al_2O_3	2.4 1	SiO_2 B_2O_3	650	1202
019	0.5 0.5	Na_2O PbO	0.3	Al_2O_3	2.6 1	SiO_2 B_2O_3	680	1256
018	0.5 0.5	Na_2O PbO	0.4	Al_2O_3	2.8 1	SiO_2 B_2O_3	710	1310
017	0.5 0.5	Na_2O PbO	0.5	Al_2O_3	3.0 1	SiO_2 B_2O_3	740	1364
016	0.5 0.5	Na_2O PbO	0.55	Al_2O_3	3.1 1	SiO_2 B_2O_3	770	1418
015	0.5 0.5	Na_2O PbO	0.6	Al_2O_3	3.2 1	SiO_2 B_2O_3	800	1472
014	0.5 0.5	Na_2O PbO	0.65	Al_2O_3	3.3 1	SiO_2 B_2O_3	830	1526
013	0.5 0.5	Na_2O PbO	0.7	Al_2O_3	3.4 1	SiO_2 B_2O_3	860	1580
012	0.5 0.5	Na_2O PbO	0.75	Al_2O_3	3.5 1	SiO_2 B_2O_3	890	1634
011	0.5 0.5	K_2O CaO	0.8	Al_2O_3	3.6 1	SiO_2 B_2O_3	920	1688
010	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.50 0.50	SiO_2 B_2O_3	950	1742
09	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.55 0.45	SiO_2 B_2O_3	970	1778
08	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.60 0.40	SiO_2 B_2O_3	990	1814
07	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.65 0.35	SiO_2 B_2O_3	1010	1850
06	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.70 0.30	SiO_2 B_2O_3	1030	1886
05	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.75 0.25	SiO_2 B_2O_3	1050	1922
04	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.80 0.20	SiO_2 B_2O_3	1070	1958
03	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.85 0.15	SiO_2 B_2O_3	1090	1994
02	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.90 0.10	SiO_2 B_2O_3	1110	2030
01	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	3.95 0.05	SiO_2 B_2O_3	1130	2066
1	0.3 0.7	K_2O CaO	0.2 0.3	Fe_2O_3 Al_2O_3	4	SiO_2	1150	2102
2	0.3 0.7	K_2O CaO	0.2 0.4	Fe_2O_3 Al_2O_3	4	SiO_2	1170	2138
3	0.3 0.7	K_2O CaO	0.05 0.45	Fe_2O_3 Al_2O_3	4	SiO_2	1190	2174
4	0.3 0.7	K_2O CaO	0.5	Al_2O_3 $4SiO_2$			1210	2210

No. of Cone.	Composition.			Fusion Point.	
				Cent.	Fahr.
5	0.3 K_2O 0.7 CaO	0.5	Al_2O_3 $5SiO_2$	1230	2246
6	0.3 K_2O 0.7 CaO	0.6	Al_2O_3 $6SiO_2$	1250	2282
7	0.3 K_2O 0.7 CaO	0.7	Al_2O_3 $7SiO_2$	1270	2318
8	0.3 K_2O 0.7 CaO	0.8	Al_2O_3 $8SiO_2$	1290	2354
9	0.3 K_2O 0.7 CaO	0.9	Al_2O_3 $9SiO_2$	1310	2390
10	0.3 K_2O 0.7 CaO	1.0	Al_2O_3 $10SiO_2$	1330	2426
11	0.3 K_2O 0.7 CaO	1.2	Al_2O_3 $12SiO_2$	1350	2462
12	0.3 K_2O 0.7 CaO	1.4	Al_2O_3 $14SiO_2$	1370	2498
13	0.3 K_2O 0.7 CaO	1.6	Al_2O_3 $16SiO_2$	1390	2534
14	0.3 K_2O 0.7 CaO	1.8	Al_2O_3 $18SiO_2$	1410	2570
15	0.3 K_2O 0.7 CaO	2.1	Al_2O_3 $21SiO_2$	1430	2606
16	0.3 K_2O 0.7 CaO	2.4	Al_2O_3 $24SiO_2$	1450	2642
17	0.3 K_2O 0.7 CaO	2.7	Al_2O_3 $27SiO_2$	1470	2678
18	0.3 K_2O 0.7 CaO	3.1	Al_2O_3 $31SiO_2$	1490	2714
19	0.3 K_2O 0.7 CaO	3.5	Al_2O_3 $35SiO_2$	1510	2750
20	0.3 K_2O 0.7 CaO	3.9	Al_2O_3 $39SiO_2$	1530	2786
21	0.3 K_2O 0.7 CaO	4.4	Al_2O_3 $44SiO_2$	1550	2822
22	0.3 K_2O 0.7 CaO	4.9	Al_2O_3 $49SiO_2$	1570	2858
23	0.3 K_2O 0.7 CaO	5.4	Al_2O_3 $54SiO_2$	1590	2894
24	0.3 K_2O 0.7 CaO	6.0	Al_2O_3 $60SiO_2$	1610	2930
25	0.3 K_2O 0.7 CaO	6.6	Al_2O_3 $66SiO_2$	1630	2966
26	0.3 K_2O 0.7 CaO	7.2	Al_2O_3 $72SiO_2$	1650	3002
27	0.3 K_2O 0.7 CaO	2.0	Al_2O_3 $200SiO_2$	1670	3038
28	Al_2O_3 $10SiO_2$			1690	3074
29	Al_2O_3 $8SiO_2$			1710	3110
30	Al_2O_3 $6SiO_2$			1730	3146
31	Al_2O_3 $5SiO_2$			1750	3182
32	Al_2O_3 $4SiO_2$			1770	3218
33	Al_2O_3 $3SiO_2$			1790	3254
34	Al_2O_3 $2.5SiO_2$			1810	3290
35	Al_2O_3 $2SiO_3$			1830	3326
36	Al_2O_3 $2SiO_2$			1850	3362

The theory of these pyramids is that the cone bends over as the temperature approaches its fusing-point. If the heat is raised too rapidly cones which contain much iron swell and blister and do not bend over, so the best results are obtained by the slow softening of the cone under a gradually rising temperature. For practical purposes these cones are considered sufficiently accurate.

In actual use they are placed in the kiln at a point where they can be watched through a peep-hole but at the same time will not receive the direct touch of the flame from the fuel. It is always well to put two or more cones in the kiln, so that warning can be had not only of the approach of the desired temperature, but also of the rapidity with which the temperature is rising.

In order to determine the temperature of a kiln several cones of separate numbers are put in, as, for example: .07, 1, and 5. Suppose .07 and 1 are bent over in burning but 5 is not affected, the temperature of the kiln is between 1 and 5. The next time Nos. 2, 3 and 4 are put in, 2 and 3 may be fused but 4 remains unaffected, indicating that the temperature reached the fusing point of 3.

These pyramids have been much used by foreign manufacturers of clay products and are coming into use in the United States.

THERMOELECTRIC PYROMETER.

Le Chatelier's thermoelectric pyrometer depends on the measurement of a current generated by the heating of a thermopile. The latter consists of two wires, one of platinum and the other of an alloy, 90 per cent platinum and 10 per cent rhodium, twisted together at their free ends for a distance of about an inch, while the next foot or two of their length is enclosed in a fire-clay tube, so that when the couple is inserted in the furnace only the end which is held near the body whose temperature is to be measured will receive the full force of the heat. The two wires connect with a galvanometer, the deflection of whose needle measures the temperature at the point where the free end of the wire couple is applied. As at present put on the market, the themoelectric pyrometer costs about $180, and the price, together with the delicacy of the galvanometer, has tended to restrict its use. There is no reason, however, why one should not

be made and put on the market for a much lower price. It is not necessary that the recording instruments shall be in the immediate vicinity of the kiln; it may be kept in another room where it is safe from dust and rough handling, and the wires can extend from there to the kiln. This pyrometer is considered to be accurate to within 10 deg. Fahr.

Seger cones are very useful for determining the completion of firing, but the thermoelectric pyrometer serves as a guide during the burning operation, indicating whether the temperature is rising slowly or quickly, and whether steadily or unevenly.

If careful records are kept of these facts during the firing of the kiln, and the results obtained compared, we are enabled to collect valuable data concerning the conditions necessary for a successful burn.

Tensile Strength of Clay.

The tensile strength or cohesive power of a clay is commonly looked upon as standing in direct relation to its plasticity, but this is not always the case. It is an important property and one having considerable bearing, especially since clays of good tensile strength tend to hang together better and resist cracking in drying. The tensile strength of different clays varies considerably and the following figures may be taken as representing the average:

Kaolins	5–10 lbs. per sq. inch.
Brick clays	60–75 or even 125 lbs. per sq. inch.
Pottery Clays	150–200 lbs. per sq. inch.
Some very plastic clays	200–400 lbs. per sq. inch.

The method commonly used for determining the tensile strength of clay is to mold the wet clay into the form of the briquette of the same shape as that used in testing cement. In making this briquette great care has to be taken with the clay that it shall be thoroughly mixed so that the briquette will be homogeneous throughout and contain no flaws. It must also be very carefully removed from the mold so that it will not be distorted in any manner, if possible. After drying and hardening thoroughly the briquette is pulled apart in a cement-testing machine (Fig. 13). The tensile strength is expressed in pounds per square inch. As the clay shrinks in drying,

it is necessary to measure the smallest cross-section of the briquette before breaking it and to calculate from this the tensile strength of the briquette whose cross-section is one square inch.

In placing the briquette in the testing machine care must be taken not only to place the briquette in straight so that the pull on it will be even, but in addition some form of material such as pasteboard or rubber must be placed between the jaws of the clips and the sides of the briquette. Air-dried clay being quite soft is very likely to be cut into by the edges of the machine clips, thus causing the briquette to break across the head instead of through the center, and before its maximum strength is reached. The higher the tensile strength of the briquette the more likely it is to break across the head unless rubber cushions are used. In order to get the average tensile strength at least 12 briquettes of each kind of clay should be tested and the position of the break noted, whether across the head or through the middle. Clays which are very plastic may sometimes develop flaws in molding, thus causing the briquette to break long before its limit of strength is reached.

The tensile strength of the Maryland clays varies considerably. Many of the silty brick-clays found in the Potomac formation show a tensile strength ranging from 60 to 100 lbs. per square inch. The Devonian-Carboniferous shales of moderate plasticity seldom exceed 75 pounds per square inch, but this is as much as many shales show which are used for paving-brick manufacture in other parts of the country. The strongest clays noted were those of the residual nature derived from the decomposition of a peridotite near Baltimore, and used in the manufacture of pottery. One of these, from Catonsville, when tested gave the high tensile strength of from 350 to 410 pounds per square inch.

While there is sure to be a certain amount of variation in the strength exhibited by any series of briquettes made from the same clay, this variation should not, if possible, exceed 12 to 15 per cent. When the results vary beyond these limits it is best to make a second series of tests.

Shrinkage.

All the clays have the property of shrinking when dried in the air and heated in the fire. The first is known as the air-shrinkage, the second as the fire-shrinkage, and both may be exceedingly variable.

AIR-SHRINKAGE.

Air-shrinkage depends partly on the amount of water absorbed and partly on the grain and texture of the clay. If a clay is examined under the microscope it is found that it is composed of a number of grains, some of which are exceedingly small, some under 0.001 inch, while others may be .01 or .02 inch in diameter, the result of this variation permitting the particles to pack themselves into a dense mass containing a number of small pores which represent the interspaces between the grains. When the clay is in the form of a dry powder these pores are naturally filled with air, but if the clay mass is brought into contact with water all of these tiny pores act as capillary tubes and at once draw the water into the clay mass, converting it into a paste, or if sufficient water is taken up, into the form of soft mud. The amount of water which the clay absorbs will naturally depend to a large extent on the fineness of the clay grains and consequently the smallness and number of the pores, for smaller pores down to a certain limit will tend to exert stronger capillarity than the large ones. If water be gradually added to the clay it increases in pastiness or plasticity up to a certain point, this probably being the condition which we might perhaps, to borrow a term from agriculture, call the optimum of plasticity. If more water be added the plasticity of the mass begins to decrease and the material rapidly changes into the condition of a soft mud, having no longer sufficient stiffness to hold together. Up to the condition of maximum plasticity the mass of clay will tend to swell in size as the water is added. If now this mixture be set aside and allowed to dry the water begins to evaporate and as it evaporates the grains of the clay are attracted towards each other until they are all touching, after which it is probable that the clay mass will no longer decrease in size. This decrease in size due to the evaporation of

FIG. 2.—EOCENE CLAY AT UPPER MARLBORO, PRINCE GEORGE'S COUNTY.

FIG. 1.—SAND WHEELS.

the water is known as the air-shrinkage, but the clay will continue to lose weight even after the air-shrinkage has ceased for the reason that even when the clay grains have gathered together as close as they can, there may still be pores in the clay which hold water, and the clay will therefore lose weight due to the passing off of this last quantity into the air after the air-shrinkage has ceased. The air-shrinkage is usually greatest in plastic clays and least in sandy clays or coarse-grained ones. The question of air-shrinkage is often an extremely important one in clay technology for the reason that if the water be allowed to escape or be driven off too rapidly from the clay during the process of air-drying the ware may not only shrink unevenly and warp but it may also crack. Coarse-grained clays can usually be dried more rapidly than fine-grained ones on account of the fact that their pores are larger, permitting the water to escape more easily and also more rapidly. If fine-grained clays are dried too quickly the surface shrinks more rapidly than the interior and consequently cracks may be formed, especially if the clay has a low tensile strength or if it is highly plastic.

The air-shrinkage begins almost as soon as the clay is molded and taken from the machine, taking place with considerable rapidity at first but decreasing with time. While it is in most cases completed before the brick or other piece is placed in the kiln still the final portions of the moisture are not driven off until the beginning of the burning, or during the stage of firing known as "water-smoking."

FIRE-SHRINKAGE.

In the burning of clay it undergoes a second decrease in size, which has already been referred to as the fire-shrinkage, and this may vary from but 2 or 3 per cent up to 15 or 20 per cent, or even more. The fire-shrinkage may show just as much variation as the air-shrinkage, but is due to different causes. In the process of burning, the clay probably does not shrink much from the time it enters the kiln until a temperature of dull redness is reached. Up to that point the changes which are taking place are chiefly chemical ones, such as the oxidation of the iron and the driving off of organic matter, although the latter must be entirely completed during this portion

of the process. When the temperature of the kiln reaches dull redness, fire-shrinkage begins. This fire-shrinkage is partly due to the driving-off of the organic matter and possibly of the carbonic acid, but more especially to the dissociation of hydrated compounds which exist in the clay and the volatilization of the chemically combined water contained in such minerals as kaolinite, limonite, and perhaps hydrous silica, which is no doubt present in some clays. While most clays shrink in burning there are, on the contrary, some which appear to expand, and this is true of many quartzose clays, for it is known that quartz has the property of expanding at high temperatures, so that if the clay contains a large quantity of quartz the swelling of the latter under the action of great heat may not only tend to counteract the shrinkage due to other elements in the clay, but the amount of expansion of the quartz grains may exceed the shrinkage of the other grains and therefore cause the clay mass as a whole to increase in size in burning. Since the effect of quartz on the fire-shrinkage is well-known it is often added to the clay in the form of sand in common bricks or in the form of powdered quartz in the case of porcelain and white earthenware to diminish the fire-shrinkage. There is, however, the point beyond which the addition of quartz should not proceed, for the addition of quartz also decreases the plasticity and tensile strength and therefore if too much of the material be added the clay mixture will not only resist molding, but will also be so lacking in tensile strength that the objects after molding often will not hold together during the drying.

Clays containing a large amount of feldspar will show a steady shrinkage up to a temperature of complete vitrification, and often show a temporary increase in volume when the fusing point of feldspar is reached. In view of this fact it is therefore of interest to know whether the sandy or gritty grains which are sometimes easily detectable in the clay are grains of feldspar or grains of quartz, especially if the material is to be used for refractory or semi-refractory purposes.

The shrinkage of most clays in burning does not proceed regularly and steadily to the temperature of vitrification, for some reach their

maximum or nearly maximum density at a comparatively low temperature far below that at which they vitrify, and this character often gives them special value. The fire-clays used, for example, in the manufacture of glass pots and blocks for glass tank-furnaces illustrate this point.

Classification of Clay Deposits.

Few things are more difficult than an attempt to group together the different classes of clay deposits for the reason that they grade into each other to such a large extent. Whatever classification is adopted should possess if possible not only simplicity, but also value for the practical clay-worker.

Classifications which are based on the uses of a material are unsatisfactory; firstly, because clays differing widely in their form or origin would have to be placed in the same group; and secondly, because any one clay may sometimes have a number of different applications.

A classification based on origin is perhaps the best since it, of necessity, takes the form of the deposit into account.

The following scheme suggested by the writer will, it is hoped, be found useful:

1. Residual clays.
    a. White-burning (kaolins).
    b. Colored-burning.
2. Clastic, or mechanically formed clays.
    a. Water-formed.
        1. White-burning.
        2. Colored-burning.
    b. Glacial clays (often stony).
    c. Wind-formed clays (some loess).
3. Chemical precipitates. Some flint clays.

The origin of residual clays has been already explained on a previous page. They naturally fall into the two groups mentioned,

namely, the white-burning ones, or kaolins, which are commonly vein formations, and the colored-burning ones, which are represented by the residual ones found all over the South. It would of course be possible to subdivide the latter group, differentiating perhaps between those formed from limestone, shales, granites, basalts, etc., but there is no special value in doing so, for they are all more or less ferruginous and usually quite plastic.

Mechanically formed or clastic clays are those which are made up of finely divided, more or less decomposed rock fragments. The white-burning ones will be represented by the ball clays and the colored-burning ones might be still further subdivided into: (a) refractory or fire-clays: (b) stoneware, or semi-refractory clays; and (c) brick and terra cotta clays.

All of the clays of this group are stratified.

The wind-formed clays are represented by some of our loess deposits found in the western States. They are usually fine-grained, homogeneous and fairly plastic. It must be mentioned, however, that some loess is undoubtedly a water formation.

Glacial clays are those found in the drift and usually represent comminuted rock. They are often very stony and frequently lack stratification. At times they are very calcareous.

Chemically precipitated clays are probably rare, but in the United States are supposed to be represented by certain basin-shaped deposits of flint clay found in Missouri.

Uses of Clay.

So few people have even an approximate idea of the uses to which clays are put that it seems desirable to call attention to them briefly. In the following table an attempt has been made to do this.[9]

Domestic.—Porcelain, white earthenware, stoneware, yellow ware and rockingham ware for table service and cooking; stoves of majolica; polishing brick, often known as bath brick; fire-kindlers.

Structural.—Brick, common, front, pressed, ornamental, hollow, glazed; adobe, terra cotta, roofing tile; glazed and encaustic tile;

[9] Table compiled by R. T. Hill and modified by H. Ries.

drain-tile; paving brick; chimney-flues; chimney-pots; door-knobs; fire-proofing; terra cotta lumber; copings; fence-posts.

Hygienic.—Urinals, closet bowls, sinks, wash-tubs, bath-tubs, pitchers, sewer pipe, ventilating flues, foundation blocks, vitrified bricks.

Decorative.—Ornamental pottery, terra cotta, majolica, garden furniture.

Minor uses.—Food adulterants, paint fillers, paper filling, electrical insulators, pumps, filling cloth, scouring soap, packing horses' hoofs, chemical apparatus, condensing worms, ink bottles, ultramarine manufacture, emery wheels.

Refractory wares.—Crucibles and other assaying apparatus, gas retorts, fire-bricks, glass-pots, saggers, stove and furnace bricks, blocks for fire-boxes, tuyères, cupola bricks.

Engineering work.—Puddle, portland cement, railroad ballast, water conduits, turbine wheels.

Prospecting.

No fixed rules can be laid down for the guidance of the prospector and clay-worker in a state whose clays have such a wide range geologically as do those of Maryland.

In the western part of the State, as in Allegany and Garrett counties, the clay and shale deposits often occupy well-marked stratigraphic positions and are commonly quite persistent. In the eastern portion, or Coastal Plain area, the deposits while often large locally cannot be traced for long distances, although similar ones are likely to occur at other points in the same formation.

The two important points to be remembered are, first to locate the deposit and secondly to prove its extent.

The existence of the differences between west and east mentioned above necessitate two entirely different methods of procedure.

In that portion of the State underlain by rocks of Silurian, Devonian, Carboniferous or Triassic age, the strata are often folded and upturned, and consequently, in going across the country in a direction at right angles to the strike, one passes over the edges of the

different beds. This affords a good clue to the character of material providing the covering of loose material is not too heavy, in which case it would be necessary to search for outcrops on the steeper hillsides, in railroad cuttings, or the embankments of wagon roads. Shales which weather down easily to a plastic mass are usually those which grind up easily and form a very moldable mass with water.

In many portions of the State the rocks have broken down under the action of weather to a residual clay. This is true of all kinds of shales, limestones, granites, etc., and as already mentioned, these usually pass downward into the parent rock. Such residual deposits vary considerably in thickness, and are likely to be heaviest on surfaces having little or no slope, for those formed on the hillsides wash away quite rapidly. They are often used in the manufacture of common brick.

In the eastern portion of the State the Algonkian gneisses have yielded an abundance of white or yellowish white residual clay, which, however, is often covered by a mantle of Potomac deposits. In the exploitation of these kaolins great care should be taken to prove the thickness of the deposit either by test pits or boring, for the rock has not been decomposed to the same depth in all places, neither is the amount of overburden constant.

The materials washed off the hillsides often accumulate in the valley bottoms, and in such locations are frequently exploited for the manufacture of brick, or in rarer instances for wares of better grade.

Such sedimentary beds may or may not be extensive. They may also vary vertically from those of a sandy nature to others of high clay percentage.

It is in the Coastal Plain region, however, where the greatest care must be exercised in prospecting. Here, in the Cretaceous, Tertiary and Pleistocene formations, there has been deposited as great a variety of plastic materials as one could wish to find. They vary from materials as silicious as glass sands to the finest-grained modelling clays. Since the beds are horizontal, or nearly so, it is not possible to follow across the edges of them. The region, however, in which these clays occur is abundantly dissected by rivers, brooks

and gullies, and along the banks of these many fine sections are exposed. The shores of Elk Neck, in Cecil county, and the valleys of the Severn, Magothy, and Potomac rivers farther south are in places lined with bluffs affording excellent sections.

Much additional information is also obtained from an examination of railroad cuttings, and in the digging of wells, and drainage ditches.

Since, however, the Coastal Plain clay beds are often lens-shaped in outline and may pass laterally into the most unlike materials, it is highly important to prove the extent and thickness of the deposit after it is discovered.

Another important point to be considered is the quantity of overburden, and distance of deposit from the shipping point. A bed of good clay may often be covered by such a thickness of useless material as to prohibit its being worked profitably.

The price of raw clay is usually so low also that a long haulage can only be considered for kaolins or high-grade fire-clays.

Mining and Quarrying.

Shales and very hard clays often have to be quarried by the same means employed for building stone. Where the shales are interbedded with sandstone, coal, or other rock, and the amount of overburden is too great to be stripped off, underground methods must be resorted to. These usually consist simply of a tunnel running in from the outcrop and radiating entries from this. This plan as followed at the fire-clay mines along Savage Mountain is shown in Plate XXII, Fig. 2. Timbering is commonly necessary to hold up the main tunnel or drift and its branches so that the cars can be run directly to the working face.

In soft clay deposits the pit method of working is almost invariably adopted. This consists in digging out the material by means of pick and shovel and loading it onto cars, as shown in Plate XXII, Fig 1. Where there is much sand overburdening it, it is usually found economical to remove this by means of plows and scrapers.

The clay itself is usually dug by means of mattocks and spades, those often used being narrow with a slight curve. If the clay is

very plastic, as some stoneware-clays are, it is dug out in large rectangular lumps. Steam-shovels and dredges of the clam-shell type have been employed where the output is large, but otherwise they are expensive. The only locality in Maryland where a steam-shovel is employed is in the pits of the Maryland Clay Company, at Northeast, Cecil county.

Where the shale beds are inclined, it is customary to mine out those beds which are desired and leave the others standing, supported by pillars of shale or timbers (Plate XX, Fig. 1).

Much time and money can be saved in the proper handling of the material after it is dug. Where the distance from the pit to the works is but a few feet, wheelbarrows are mostly used, but for leads of from several hundred feet upwards it is more economical to lay a narrow-gage track for cars, which are hauled by horse-power or occasionally by cable. Steam-haulage is economical for distance of say not less than 600 feet and provided the locomotive is kept constantly employed.

Purification of Clay.

While many clays, especially those used in the manufacture of the lower grades of clay products, can be used in the condition in which they are mined, still others have to go through a process of purification or preparation which may serve either to free the clay from impurities or to render it more homogeneous in texture (by breaking it up into its elementary constituents) or both. The methods used are weathering, screening, washing and air-separation.

WEATHERING.

This is perhaps one of the most effective means of breaking up a clay mass and increasing its plasticity. Clays if laid out on the ground will usually disintegrate more or less thoroughly. This change takes place partly as a result of frost action and partly, it is considered, through the action of escaping gases, such as carbon dioxide, which may be evolved if the clay contains organic matter. This custom is followed by many manufacturers of fire-brick and pressed brick. The process may also bring about other changes,

FIG. 1.—TROUGHING FOR KAOLIN-WASHING.

The Friedenwald Co.

FIG. 2.—SETTLING TANKS AT KAOLIN-WASHING PLANT.

especially if the clay contains iron compounds. Thus many refractory clays contain lumps of siderite or pyrite, which may sometimes escape observation, but on exposure to the weather they change to limonite and can thus be readily picked out of the mass.

Pyrite may, however, also give rise to the formation of soluble sulphates, which cause trouble in the manufactured product if means are not taken to render them harmless.

SCREENING.

This method is seldom used and finds application chiefly with these clays which contain pebbles of injurious minerals. Even then the material has to be first dried before it can be put through the sieve.

WASHING.

Low-grade clays are rarely washed in the United States, but abroad the simple washing process is often used to free the clay from an excess of sand.

Clays are washed by one of two methods. With the first method, the clay is thrown into large circular tubs filled with water, in which it is stirred up by revolving arms and the clay lumps thereby disintegrated. By this treatment the fine kaolinite particles, as well as very fine grains of mica, feldspar and quartz, remain suspended in the liquid, while the coarser grains settle in the bottom of the tank. The water with the suspended clay is then drawn off to the settling tanks.

A modification of this consists in the use of a large cylinder, closed at both ends, which is set in a horizontal position, and contains an axis with iron arms, their revolution serving to break up the clay, which is charged through a hopper at the top. A current of water passes through the cylinder and carries the fine clay particles with it, while the coarse ones are left behind in the machine. The speed of the current has to be regulated by experiment, for if too much water is used coarse material will be washed out of the cylinder, and conversely if the current is too slow the clay will not yield a sufficient percentage of washed product. One objection to this apparatus is

that it has to be stopped from time to time to remove the coarse sand from the machine.

The method most commonly used at the present day for washing kaolin is in its general detail as follows:

As the kaolin comes from the mine it is generally discharged into a log washer, a semi-cylindric trough, in which revolves a horizontal axis bearing short arms. The action of the arms breaks up the kaolin more or less thoroughly, according to its density, and facilitates the subsequent washing. The stream of water directed into the log washer sweeps the kaolin and most of the sand into the washing trough, which is about 15 inches wide and 12 inches deep, but should be wider and deeper if the kaolin is very sandy. The troughing arranged as shown in Plate XXIV, Fig. 1, is about 700 feet long, and to utilize the space thoroughly it is broken up into sections (50 feet each is a good length), these being arranged parallel and connecting at the ends, so that the water, with suspended clay, follows a zigzag course.

The troughing has a slight pitch, commonly about one inch in 20 feet, but the amount depends on the kaolin and whether the contained sand is fine or coarse. If the kaolin is very fine and settles slowly, the pitch need not be so great, and vice versa. A large quantity of very coarse sand in the kaolin is a nuisance, as it clogs up the log washer and the upper end of the trough more quickly, causing much labor to keep them clean. As it is, considerable sand settles there, and to keep the trough clear, sand-wheels are used (Plate XXIII, Fig. 1). The wheels are wooden, bearing a number of iron scoops on their periphery. As the wheels revolve the scoops catch up a portion of the sand which has settled in the trough, and as each scoop reaches the upper limit of its turn on the wheel it, by its inverted position, drops the sand outside the trough. These sand-wheels are a help, but it is often necessary in addition to keep a man shoveling the sand from the trough. If the sand is finer it is not dropped so quickly and, distributed more evenly along the trough, does not clog it up so fast.

The zigzag arrangement of the troughing has been objected to by

some as it produces irregularities in the current, causing the sand to bank up in the corners, at the bends and at certain points along the sides of the troughing.[10] The effect is to narrow the channel and consequently increase the velocity of the current, thereby causing the fine sand to be carried still farther toward the settling tank. This difficulty, which is not often serious, has been obviated either by having the troughing straight or by allowing the water and suspended clay as they come from the log washer to pass through a section of straight trough, and from this into another of the same depth but 5 or 6 times the width, and divided by several longitudinal partitions. The water and the clay then pass into a third section, twice as wide as the second, and divided by twice the number of longitudinal divisions. By this means the water moves only in a straight course, but as it is being continually spread out over a wider space it flows with an ever-decreasing velocity.

By the time the water has reached the end of the troughing nearly all the coarse grains have been dropped and the water is ready to be led into the settling vats, but as a further and necessary precaution it is discharged on a screen of 100 meshes to the linear inch, with the object of removing any coarse particles that might remain, and also of eliminating sticks and other bits of floating dirt.

Two kinds of screens can be used, the first stationary, the second revolving. The stationary screen is simply a frame covered with a copper cloth and set at a slight angle. The water and suspended kaolin fall on the screen and pass through, otherwise they run off and are lost. A slight improvement is to have two or three screens overlapping one another, so that whatever does not get through the first will fall on the second. If the vegetable matter and sticks are allowed to accumulate they clog the screen and prevent the kaolin from running through; consequently stationary screens must be closely watched.

The revolving screens are far better for they are self-cleansing. Such screens are barrel-shaped, and the water, with the kaolin in suspension, is discharged into the interior and passes outward through

[10] E. Hotop. Thon Industrie Zeitung, 1893.

the screen cloth. As the screen revolves the dirt caught is carried upward and finally drops; but, instead of falling down on the other side of the screen, it falls on a board, which diverts it out to the ground.

The settling tanks, into which the kaolin and the water are discharged, may be and often are about 8 feet wide by 4 feet deep and 50 or more feet long (Plate XXIV, Fig. 2). As soon as one is filled the water is diverted into another. The larger a tank the longer it will take to fill it and allow the kaolin to settle. Clays obtained

FIG. 10.—The "Johnson" square center feed open delivery filter press.

in this manner are expensive, particularly when the market takes the output of washed kaolin as soon as it is ready. Small tanks have the advantage of permitting the slip to dry more quickly, especially when the layer of clay is not very thick; furthermore, a small pit takes less time to fill and empty. But one disadvantage urged against a number of small tanks is that a thoroughly average product is not obtained, owing to the thinness of the layer of settlings and the small amount in each. In addition a series of small tanks require considerable room. The advantages asserted in the case of large tanks are that the clay can be discharged into any one for a considerable

period, and if the clay deposit varies in character the different grades get into one tank and a better average is thereby obtained.

If the kaolin settles too slowly, alum is sometimes added to the water to hasten the deposition. When the kaolin has settled, most of the clear water is drawn off; the cream-like mass of kaolin and water in the bottom of the vat is drawn off by means of slip pumps and forced by these into the presses.

The press consists simply of flat, iron or wooden frames between

FIG. 11.—Press used for compacting washed kaolin.

which are flat canvas bags (Figs. 10-11). These bags are connected by nipples with a supply tube from the slip pumps, and by means of the pressure from the pumps nearly all of the water is forced out of the kaolin and through the canvas. When as much water as possible is squeezed out, the press is opened and the sheets of semi-dry kaolin are taken out. It is then dried either on racks, in the open air or in a steam-heated room.

As for every ton of kaolin usually only about two-fifths or one-quarter of a ton of washed kaolin is obtained, it is desirable to have the washing plant at the mines, to avoid the hauling of 60 or 70 per

cent of useless sand which has to be washed out before the kaolin can be used or even placed on the market.

AIR-SEPARATION.

This is a method of cleansing clays which has rarely been tried, yet in some of the cases where it has been used it is said to have met with success. It is especially applicable to those clays from which it is necessary to remove simply coarse or sandy particles. The process in brief consists in feeding the dry clay into a pulverizer which reduces it to the condition of a very fine powder. As the material is discharged from the pulverizer into a long box or tunnel, it is seized by a powerful current of air which at once picks up the fine particles, carrying them along to the end of the airway, where they are dropped into a bin. The coarser particles which are too heavy to be picked up by the current drop back and are carried through the pulverizer once more. Such a method would be especially applicable to kaolins which are free from iron, but in those containing ferruginous particles, air-separation would not be found adaptable in the majority of cases.

There are several forms of separators on the market.

In the Raymond pulverizer[11] and separator (Fig. 12) the material is pulverized in the lower part of the machine and then thrown upward, the finer particles being carried off by a fan to the discharge hopper, the coarser ones falling back into the hopper.

THE TESTING OF CLAYS.

Since the erection of a plant for treating clay and manufacturing clay products, especially if erected in accordance with modern ideas and equipped with modern machinery, requires an outlay of considerable capital it is highly desirable to have some means of telling in advance by cheap methods whether the clay is adaptable for the purpose desired, or if not suitable for that purpose whether it cannot be used in some other direction. To meet this want it has been found desirable and possible to devise methods for testing the clay in

[11] Made by the Raymond Bros. Impact Pulverizer Co., of Chicago.

the laboratory, which give a very fair idea concerning the value of the material.

In Europe, and more especially in Germany, laboratory methods of clay investigation, especially of a physical nature, have been in use for some time, but in this country their introduction is relatively quite recent. The custom which has usually been followed in the

Fig. 13.—Raymond pulverizer and separator for cleaning clays.

United States has been to send several barrels of the clay to the manufacturer of some form of machinery, who for a small sum puts the clay through a test, in many cases producing a first-class product. This method is very unsatisfactory and is often quite misleading in its results. A better plan, and one sometimes adopted is to send the clay to some clay-working establishment, and there have it put through some test on a working scale. Here again the error is made

of sometimes molding the clay by one method or in one type of machine only. Experience shows that clay which works admirably with one make of machine may not work at all with another type. The testing of clays in the laboratory does not attempt to entirely supplant practical tests of a working scale, but nevertheless it affords many clues which are often of considerable value. The tests commonly carried out in the laboratory investigation are the following: Determination of the plasticity; percentage of water required to work up the clay; tensile strength; air and fire-shrinkage; color when burned; fusibility, the degree of refractoriness; and general character of the burned product. These points may all be classed as physical ones and should in many cases be of considerable practical value to the clay-worker.

In addition to the physical tests chemical ones are sometimes carried out, these consisting in making an ultimate and sometimes a rational analysis of the clay, as well as the determination of the percentage of soluble salts which the material contains.

The chemical tests are unfortunately of much less value to the practical clay-worker than the physical ones for the reason that while the results obtained in the latter case are clearly intelligible to him, those obtained in the former may require some special knowledge for their proper interpretation.

Physical Tests.

The percentage of water to mix up the clay is usually determined by mixing up the material with water until it reaches a condition of as much plasticity as it is apparently capable of developing. While, of course, there is bound to be some variation in the results of the test, due to the personal equation of the person making the experiment, at the same time the results obtained are moderately accurate. It is found that the amount of water required by different clays in order to develop their maximum plasticity varies considerably. The degree of plasticity can only be expressed in general terms, for up to the present time no successful means has been devised for testing the plasticity of the clay and expressing this degree of plasticity numerically. We are therefore obliged to use such terms as *lean*,

moderately plastic, and *very plastic*, the latter term being applied to those clays which are exceedingly sticky and hard to work, while the term lean is used in the case of those materials which show very little pastiness; in fact, sometimes hold together very slightly.

SHRINKAGE.

The shrinkage of samples is determined by making them up into bricklets. These bricklets have different sizes to suit the individual tastes of the person making the tests. In order to determine whether a clay will stand rapid drying either in the air or in an oven it is extremely necessary that the brick should be made as large as a machine-molded one, otherwise no results of value will be obtained. The same clay if made up into bricklets a few inches in length and perhaps an inch thick will stand very rapid drying in a heated air-bath, whereas if it is made up into bricks 7 or 8 inches long, 4 inches wide and 2 to 2½ inches thick, it may, when put in the air-bath, develop the most pronounced series of cracks unless it is dried evenly and very slowly. The air-shrinkage of the clay when dried under normal conditions usually is determined by drawing several straight lines on the bricklet, one nearly its entire length on the top, another on the same surface, transversely to that and the third on the side of the bricklet. These lines are very carefully marked by means of some sharp edge such as a knife blade, and their length is measured when first made and also when the brick is thoroughly air-dried. It is perfectly possible to measure these lines with an inch rule divided into 100ths of an inch. The decrease in the length of these lines gives us the air-shrinkage, which as usually expressed is the linear shrinkage, although by having three lines the cubical decrease could be determined, but this is not necessary since it stands in direct relation to the linear shrinkage.

FIRE-SHRINKAGE.

The fire-shrinkage is determined by measurng these same lines after burning the bricklet at different temperatures as is commonly done.

TENSILE STRENGTH.

In order to determine the tensile strength of a clay or the resistance which it offers to being pulled apart on account of the particles of clay being interlocked, the method usually followed is to mold the wet clay into the form of briquettes similar to those used in testing the tensile strength of hydraulic cement. Indeed, the same kind of briquette mold may be used for forming them. Much discussion has arisen over the proper way in which to mold these bricks, some clay technologists claiming that the material should be stamped into the mold piece by piece, others believing that the clay should be put into the mold in one solid piece and its form changed as little as possible after insertion into the mold. A third method of procedure is to take a lump of the thoroughly tempered clay, about enough to a little more than fill the mold, squeeze it roughly into the shape and then force it into the mold, pounding it several times

FIG. 13.—Machine used for testing the tensile strength of clays.

after it is in. Just which of these methods is the best still remains to be seen. After filling the mold the excess of clay is carefully scraped off either by means of a knife-blade or a fine wire, and the briquette may be removed from the brass form and set aside to dry. It is of the highest importance that this drying of the briquette should proceed carefully at first, otherwise cracks are likely to develop, especially in the case of fine-grained clays, which may seriously lower the tensile strength of the brick. The briquettes are first carefully dried in the air and later in a hot-air bath, the amount of time required for each being determined by the appearance of the briquette and also the weather. When thoroughly dried they are put in the brick machine and their tensile strength determined. This tensile strength is expressed in pounds per square inch. The briquettes as molded have a cross-section of one square inch, but since this of course diminishes on drying it is necessary to re-measure the cross-section of each briquette before it is broken, in order to calculate its tensile strength per square inch after breaking. If properly made the briquette should break along a straight line at the point of its smallest cross-section. It sometimes happens, however, that it does not do this but instead breaks up near the head. This may be due to flaws in the briquette, which are sometimes likely to occur in the case of very plastic clays. It may also be due to the action of the clips, which sometimes tend to bite the briquette in two, thus causing it to break before the actual limit of strength has been reached. The writer, in testing briquettes, has found that if pieces of heavy pasteboard or thick rubber be placed between the clip surface and that of the briquette, there is much less danger of an irregular break. The tensile strength of clays as stated on another page varies considerably and the results may range from five or six up to four hundred or more pounds per square inch in their air-dried condition. In testing the tensile strength of the clay no fewer than 12 or 15 briquettes should be made and broken in order to get a good average, and it is desirable that there should be as little variation as possible.

Since the cross-section of the head of the briquette is greater than

the centre, it is safe to assume that when a break occurs in the head it will not be less than the pull which the centre could withstand, and can therefore be averaged in.

FIRE TESTS.

The behavior of a clay under fire is sometimes tested in a small experimental kiln, at other times in a gas furnace or even a coal furnace such as assayers use. There are several types of furnaces on the market which work either by natural draft or by means of a blast. One of the simplest forms of these is that known as a Fletcher furnace (Fig. 14), which is simply a cylindrical furnace adapted to

FIG. 14.—Fletcher furnace used for testing clay samples.

hold either a crucible or a muffle and which is heated by means of a blast which may be inserted into an opening in the side of the furnace. The size of these furnaces is not very great and consequently the bricklets which can be burned in them must be rather small. They also have the disadvantage of not heating up evenly throughout owing to the fact that the heat is applied to the crucible or muffle on one side only. This fault is partly overcome in some of the smaller Fletcher furnaces which use a natural draft, but in this it is not possible to reach a temperature much above 1700 deg. Fahr. One of the best laboratory furnaces in use is that constructed by Seger (Fig. 15). It is a form found in this country but little, though much used in many of the foreign laboratories. It consists essentially of a regenerative downdraft furnace heated by gas. The

furnace, a section of which is shown in the accompanying cut, is circular in form. The gas enters through a slit near the bottom of the furnace and comes from six or eight burners. The air, which is pre-heated, comes from below and is united with the gas as it issues from the burners. This mixture passes between the wall of the furnace and the fire-bridge, over the cylinder and then downward

FIG. 15. FIG. 16.

FIG. 15.—Sectional view of Seger Furnace used in testing clay samples.
FIG. 16.—Section of Deville Furnace used in testing clay samples.

between it and the crucible, thus thoroughly enveloping the crucible. It passes off around the bottom of the crusible to the off-take pipe. These furnaces are capable, it is claimed, of reaching the fusing point of cone 25. But they are probably seldom used for higher temperatures than the fusing point of cone 18, which is that attained by many hard-porcelain manufacturers. A muffle furnace similar in principle to the one just described has also been constructed. For

very high temperatures, that is, those of 3000° Fahr. and upward, it is common to use a furnace known as the Deville furnace, which, though simple and inexpensive in its construction, is at the same time capable of generating a very high degree of heat.

The Deville furnace, a section of which is shown in Fig. 16, consists essentially of a heavy cast or sheet-iron cylinder having a refractory lining from two to three inches thick. This lining may be of silica, brick, fire-brick, or magnesite. We thus have in the center of the furnace a cylindrical chamber of 3½ inches in width and perhaps 20 inches deep. At the bottom of this chamber is a heavy iron plate (a) perforated with holes, and below this is an air chamber (b) perhaps 3 inches in height. The blast, which is supplied by some form of bellows or blower, passes into this air-chamber and then upward through the small openings in the plate. A covered crucible containing the small test cones and also cones of the clay to be tested is placed in the bottom of the furnace on a perforated plate. The fire is started by putting a small quantity of burning charcoal into the bottom of the furnace and then placing on the top of this small lumps of carbon obtained from the gas retorts. The blast is at once turned on and kept up vigorously until the whole quantity of carbon is consumed and the crucible which was at first buried under the fuel is entirely visible. The blast is then stopped and the crucible removed. By means of this furnace it is possible to attain a temperature of about 3500° Fahr. in the short space of about one hour and with a consumption of 2½ to 3 pounds of the gas carbon. The blower which supplies the blast can be operated either by means of hand-power or an electrical motor, the latter being preferable as it supplies a blast of greater steadiness.

Chemical Tests.

DETERMINATION OF SOLUBLE SALTS.

These are determined by taking a small quantity, say 0.5 gram, of the powdered clay, placing it in distilled water and keeping the latter near the boiling point for several hours. At the end of this time the liquid is poured off through a filter and evaporated to dryness on a

platinum dish which has been weighed; the increase in weight gives the amount of soluble salts. Great care must be taken in filtering the material, for some clays tend to creep through the filter despite all precautions which may be taken. A very small quantity of clay which has succeeded in getting through will tend to produce an opalescence in the water, which at times may be almost imperceptible, but the solution should not be evaporated until it has been removed.

ULTIMATE ANALYSIS.

The method of carrying out the ultimate analysis of clay need not be described in any special detail, for the reason that the process is well known. The results obtained, however, are of considerable importance. In such an analysis the substances usually determined are silica, alumina, ferric oxide, lime, magnesia, the alkalies, moisture, water, and in rare cases titanium, sulphur, phosphoric acid and organic matter. The method of interpreting these results is mentioned in a subsequent paragraph.

RATIONAL ANALYSIS.

The rational analysis consists in separating the clay into its mineralogical, or so to speak, its physical constituents. Those usually determined are clay substance, quartz and feldspar.

The process can perhaps be best explained and compared with the ultimate analysis by quoting from a paper previously written by the writer on the subject:[12]

"It is a common custom of the manufacturers of porcelain, white earthenware, fire-brick, and other refractory goods—in fact of all products made from high grades of clay—to use the rational analysis as a guide in making up their mixtures and keeping them constant. The advantage of this analytical method is that it resolves the clay into its mineral components, and enables us thereby to get an insight into the physical character of the material used, which is frequently a matter of far greater importance than its chemical composition.

"The ordinary quantitative or ultimate chemical analysis regards

[12] Kaolins and Fire-clays of Europe. 19th Ann. Rep. U. S. Geol. Surv., pt. vi cont'd, p. 377.

the clay as a mixture of oxides of the elements, although they may be present in entirely different combinations, such as silicates, carbonates or hydrates, sulphates, etc. This condition of combination is of importance, for it may make a vast difference whether a material is present as a silicate or a carbonate.

"Silica if present as quartz will decrease the shrinkage and up to certain temperatures increase the refractoriness, but if present in the clay as a component of feldspar it serves the purpose of a flux and somewhat increases the plasticity."

It is not intended, though, that the rational analysis should entirely supplant the ultimate, for this is not possible, as each serves its own purpose.

The ultimate analysis may be used to supply information on the following points:

1. Purity of the clay, showing the proportions of silica, alumina, combined water, and fluxing impurities.

2. The refractoriness of the clay, for, other things being equal, the greater the total sum of fluxing impurities the more fusible the clay.

3. The color to which the clay burns. This may also be judged approximately, for the greater the amount of iron present the deeper red will the clay burn, provided the iron is evenly and finely distributed and an excess of lime is not contained in the clay. If the proportion of iron to lime is as 1 to 3, then the buff product results, provided the clay is heated to incipient fusion or vitrification. The above conditions will be affected by a reducing atmosphere in burning or the presence of sulphur in the fire gases.

4. The quantity of combined water. Clays with a large amount of combined water sometimes exhibit a tendency to crack in burning. This combined water would be shown in the chemical analysis.

5. Excess of silica. A large excess of silica would indicate a sandy clay.

These are practically all the points which the ultimate analysis explains, and they are mostly of a chemical nature. As regards the rational analysis, it may be carried out in a simple way or an elaborate one.

Most kaolins and other high-grade clays consist only of kaolinite, quartz and feldspar, the kaolinite forming the finest particles of the mass, while the balance is quartz, feldspar and perhaps some mica. The finest particles are known as the clay substance, which may be looked on as having the properties of kaolinite, for the latter is present in it in such a large excess. As each of these three components of the kaolin—clay substance, quartz and feldspar—have characteristic properties, the kaolin will vary in its behavior according as one or the other of these constituents predominates or tends to increase.

As to the characters of these three: Quartz is nearly infusible, non-plastic, has very little shrinkage, and is of low tensile strength; feldspar is easily fusible and of low plasticity by itself; kaolinite is plastic and quite refractory, but shrinks considerably in burning.

In Europe, especially Germany, the custom has been to disregard mica and figure it in as clay substance, partly because there was so little of it and partly because it was thought to be like kaolinite in its behavior. Where the mica percentage is very low, say 1 or 2 per cent, and is in a very finely divided condition, it can be neglected, but where it reaches 5 per cent or more it does not seem proper to class it as clay substance, for the reason that mica tends to decrease the plasticity, which effect increases with the coarseness of the mica. It does resemble kaolinite in refractoriness. In many of our washed kaolins now on the market there is very little mica, but some contain 8 to 10 per cent, which does not always yield to sulphuric acid treatment.

If now a kaolin containing clay substance, quartz, and feldspar be treated first with sulphuric acid, the kaolinite is decomposed into sulphate of alumina and hydrous silica. The former is soluble in water, the latter is removed by subsequent treatment with caustic soda, and we have the insoluble residue consisting of quartz and feldspar. In this residue the alumina is determined, and from this the amount of feldspar is calculated according to the following equation:

$$102 : 556 :: a : x;$$

or, molecular weight of alumina is to the molecular weight of orthoclase, as the weight of alumina is to the weight of orthoclase.

This is subtracted from the insoluble residue, and the difference is the quartz.

There is still another way of conducting a rational analysis, which is chiefly applicable when the clay contains other minerals beside the kaolinite, feldspar and quartz, such as carbonate of lime and magnesia, and appreciable amounts of ferric oxide and such mica as is attacked by sulphuric acid. This second method is Seger's method, as elaborated by Langenbeck, and may be illustrated by the following example, a fire-clay from Ohio:

	TOTAL ANALYSIS.	INSOLUBLE IN H_2SO_4.
Silica	73.21	55.38
Alumina	14.56	2.35
Ferric oxide	4.79	.39
Lime	.51	.15
Magnesia	1.07	.05
Potassium oxide	1.75	1.71
Sodium oxide	1.16	....

The insoluble residue consists of quartz, feldspar, and perhaps traces of silicate minerals approaching feldspar in composition. In orthoclase (the common feldspar) the amount of silica is about 3.51 times that of alumina. Therefore, the alumina of the insoluble portion multiplied by 3.51 gives the silica of the feldspar which, subtrated from the total silica of residue, leaves the silica present as quartz. Thus, in column 2, above we have:

	SILICA.
2.35 x 3.51 =	8.25
Alumina	2.35
Fluxes	2.20
Per cent of feldspar	12.80

Subtracting this from the total insoluble residue gives the amount of quartz.

As the clay substance, mica and ferric oxide, are the soluble portion of the clay, their composition is obtained by subtracting the insoluble residue (r) from the total analysis, thus obtaining:

Silica	17.83
Alumina	12.21
Ferric oxide	4.40
Lime	.36
Magnesia	1.02
K_2O } Na_2O }	1.20
Ignition	3.70

If we take the average composition of mica (including muscovite and biotite) as: silica, 50 per cent; alumina, 32 per cent; alkalies, 10 per cent; and other fluxes, 8 per cent, then we have:

1.2 x 3.2	3.84 alumina
1.2 x 5	6.00 silica
1.2 x 1	1.20 alkalies
1.2 x 0.8	.50 magnesia .46 iron

Subtracting column 4 from 3 gives us clay substance and ferric oxide:

Silica	11.83
Alumina	8.37
Ferric oxide	3.94
Lime	.36
Magnesia	.52
Ignition	3.70
Total	28.72

By this operation the clay has been resolved into:

Quartz	47.23
Feldspar	12.80
Mica	11.84
Ferric oxide	3.94
Clay substance	24.78

Whether it will be practically advantageous to carry out a rational analysis to this extent still remains to be seen. In its simpler form, however, when applied to high-grade clays, the rational analysis has been found to possess great practical value, owing to the fact that if two clays have the same rational composition they will, other things being equal, behave much alike when burned. This fact is made use of by the potter, for example, in the preparation of his porcelain or white earthenware mixture, also by manufacturers of enameled tiles, fire-brick, etc.

To illustrate this point, take the manufacture of porcelain. Porcelain is made from a mixture of kaolin, quartz and feldspar. Suppose that for the manufacture of porcelain or fire-brick a kaolin is used which has 67.82 per cent of clay substance, 30.93 of quartz, and 1.25 of feldspar, and that to 100 parts of this are added 50 parts of feldspar. This would give a mixture of 45.21 per cent of clay substance, 20.62 of quartz, and 34.17 of feldspar. If now for the clay used one is substituted with 66.33 per cent of clay substance, 15.61 of quartz, and 18.91 of feldspar, and with no other changes, the mixture would then contain 44.22 per cent of clay substance, 10.41 of quartz, and 45.98 of feldspar. This last mixture shows such an increase in feldspar that it must give much greater shrinkage and fusibility; but, knowing the rational analysis of the new clay, it would be easy, by making a simple calculation, to ascertain how much quartz or feldspar should be added to bring the mixture back to its normal composition.

Geographic Distribution of Clays.

Since the clay resources of the State of Maryland are so varied and are so abundant, although they are developed to only a comparatively small extent, it may be interesting for the sake of comparison to speak briefly concerning the distribution of clay deposits in other parts of the United States.

ALABAMA.

The clays in this state are very similar geologically to those found in the State of Maryland for the reason that they predominate in the Coastal Plain formations. In the Cretaceous formation there are a number of clay beds of different qualities which occur in the belt extending over Columbus into the northwestern corner of the state, while fire-clays are chiefly found at Woodstock, Bibbville, Oxford, and other localities. Cream-burning clays are found at Oxford, and similar materials are also quarried at Anniston and at other points in the Coosa Valley region. Good deposits of terra cotta and stoneware clay are also found along the line of the M. & B. R. R., especially west of Tuscaloosa, at a locality known as Sand Mountain. Some

of the red and purple clays of the Tuscaloosa formation seem to be well adapted to the manufacture of vitrified brick. Brick clays and loams are naturally very common in the bottom-lands which border many of the rivers of the Coastal Plain, while the Coal Measures contain siliceous material suitable for the manufacture of red paving brick. Some white-burning clays are also found in the Carboniferous at Fort Plain. The deposits found in the northeastern part of the state afford a material of high refractoriness.

ARKANSAS.

Many clay deposits are found in both the Cretaceous and Tertiary formations of this state, and while some of them appear to be suitable for the manufacture of pottery, still they have been little developed. Deposits of true kaolin are said to occur in Pulaski county, while white-burning sedimentary clays are found in Pike, Saline and Ouachita counties.[13] Brick clays are naturally very abundant in the stream valleys, and bricks are made at Little Rock, Texarkana, Arkadelphia, etc., while paving-brick are manufactured at Fort Smith.

COLORADO.

Although only a few of them are used, this state contains a variety of clays in the Jura-Trias, Cretaceous and Tertiary deposits along the eastern foothills of the Rocky Mountains, and also westward from Pueblo to Parkdale. Beds of fire-clays and pottery clays are also often interbedded with layers of Dakota sandstone and coal of lignitic character. Many of these clays are of high refractoriness, and those found west of Denver, near Golden, form the basis of supply for the factory making assayer's goods at Denver, namely, the Denver Fire-clay Company. These same clays are in places also worked for the manufacture of pressed-brick and paving-brick, as at Golden, Boulder and La Junta. The loess forms a brick material of great abundance throughout the eastern part of the state.

CONNECTICUT.

This state is very poor in clay material, and the clays which are found are chiefly of Quaternary age, being found in great abundance

[13] Mineral Resources, U. S. Geol. Survey, 1891, p. 516.

in the Connecticut Valley, where they are extensively used for the manufacture of common brick. These Quaternary clays are very similar to those found in the Hudson Valley of New York state and also in northern New Jersey.

DELAWARE.

Kaolin of excellent quality is extensively found at Hockessin, Newcastle county, and belongs to the same formation as the kaolins mined in Cecil county, northeastern Maryland. Some Cretaceous fire-clays and certain Columbia loams have also been worked in this state.

FLORIDA.

The most important clay resources of this state consist of very pure ball-clays, which are often erroneously called kaolins. These ball-clays form an important deposit which is often as much as 30 feet thick in the vicinity of Edgar, and also along the Palatlakaha river. The material from these deposits is shipped to many pottery centers of the United States. Common brick-clays abound here as they do in practically every other state, and in addition is found the peculiar type of clay known as fuller's earth, which has the peculiar property of bleaching oil. This latter material has been found chiefly in the vicinity of Quincy.

GEORGIA.

Building brick are made at many localities. They are of alluvial clays of Columbia age or of residual clays which occur in the area underlain by crystalline rocks. Kaolins have been found resulting from the decomposition of the Knox dolomite and probably may occur in other localities, where they have been formed by the decomposition of the feldspar veins.

The Potomac formation contains clays which are white, or nearly white, in color, and are said to be quite refractory.[14]

INDIANA.

The clays of this state are of three types, namely: residual clays derived from limestones or other rocks; sedimentary clays, at times

[14] G. E. Ladd, Amer. Geologist, April, 1899, page 240.

surface deposits, more often shales and fire-clays of Paleozoic age, which are interbedded with sandstones and coal; and thirdly, glacial clays, which are found chiefly in northern and central Indiana. The fire and stoneware clays are often mined in connection with coal, and sometimes form persistent beds occupying well-marked stratigraphic positions.[15]

KANSAS.

Most of the clay deposits of this state are surface beds of Quaternary age. The loess is extensively used in the eastern counties, and at Pittsburg a ten-foot bed of fire-clay occurs which is used in the manufacture of paving-brick. Fire-clays also occur at a number of other localities in association with the coal beds, but they have been used to no great extent.

KENTUCKY.

The clays of Kentucky are in several geological formations. Residual clays are found in many localities, having been derived from the limestones, as in the celebrated Bluegrass region. In the Cretaceous of western Kentucky there is an abundance of brick, fire and pottery clay, while in the Coal Measures fire-clays and clays for paving-brick are also said to occur. One deposit which has been worked to some extent is found at Graham station in Carter county. Pottery clay is found chiefly in the Tertiary beds which are found in the Jackson Purchase region. Clays are said to exist in Ballard, Hickman, Marshall, McCracken, Carlisle and Calloway counties, but their value has not yet been commercially demonstrated.

LOUISIANA.

The clays of Louisiana are all Post-Tertiary and sedimentary in their origin. There are no important residual clays in the state except in one very small area. This is in the northeast corner, near the Arkansas line. Three distinct types of clay are worked in Louisiana, each being characteristic of the section of the state in which it is found. The oldest of these geologically is the mottled gray clay of southeast and southwest Louisiana. These clays are

[15] See 20th and 22d Annual Report of Indiana Geol. Survey.

of early Columbia age, and constitute the pine flats of the coast and the second bottoms of the coastal streams. They have been worked for a long time locally for the manufacture of common building brick, but only in the last few years have they been utilized on a large scale.

The next important group of clays is of a later Columbia age and is found above the alluvial valley of the modern Mississippi river. They form a continuous bluff overlooking the river from the Mississippi state line to Baton Rouge. Thence they bear southeastward to near Lake Maurepas. These clays have been extensively worked around Baton Rouge; they make a good quality of building brick, but at many places they are covered with a great thickness of loess. Similar clays of the same age form a series of bluffs on the western side of the present Mississippi valley from the Arkansas state line to the Gulf of Mexico. These clays have been worked at Marksville, Washington and New Iberia. At the latter place a good dry-pressed brick is made from them.

A third group of clays comprises a series of pocket-like deposits in the modern alluvium of the Red River. They probably represent abandoned portions of the river-bed. In addition to these three main groups of clays, others of Lafayette age occur in northern Louisiana. Lignitic shales are also found in certain portions of northern Louisiana near Shreveport. These may perhaps be suitable for the manufacture of paving-brick.

MAINE.

The clay industry of Maine is on the decline. There are a number of brick-yards along the coast, which in former years sent their product to Boston, but the establishment of local yards around the latter city has had a bad effect on this trade. Two stoneware potteries, one at Portland, the other at Bangor, are still in operation, but they draw their material largely from other states. The clays found in Maine are all of Quaternary age.

NEBRASKA.

The clay resources of this state are similar to those of Kansas. Brick clays are used locally in the vicinity of the more important

towns. A fine kaolin-like clay is found on Pine Creek in Cherry county.

NEW JERSEY.

In 1878 the New Jersey Geological Survey issued an extremely valuable report on the clay resources of that state. The clays of New Jersey are Quaternary, Tertiary and Cretaceous, the latter including beds of fire-clays, fire-sands, and white-burning clays, which are commonly, but erroneously, called kaolins.

The clays extend across the state in a belt 5 to 8 miles wide, from Perth Amboy to Trenton. The deposits on Staten Island are a continuation of this belt. There are three districts recognized.

The section exhibited by the clay deposits involves the following members, beginning at the bottom:

1. Raritan potters' clay bed.
2. Raritan fire-clay bed.
3. Fire sand.
4. Woodbridge fire-clay, a most important bed.
5. Pipe clay.
6. A bed of feldspar, commonly called kaolin, being really a mixture of kaolinite with white quartzose sand, and fragments of quartz which are rounded on their edges.
7. Another kaolin bed.
8. South Amboy fire-clay bed, 20 feet thick.
9. Stoneware clay.

These form the basis of an important fire-brick and pottery industry.

The Quaternary brick-clays are abundant in the region around Hackensack, near New York City.

Recently important beds of light or white-burning plastic clays have been developed in the Tertiary formation of southeastern New Jersey.

NEW YORK.

The clays of New York are mostly of Quaternary age, forming basin-shaped deposits on the surface in many parts of the state or fringing the valleys of the Hudson and Lake Champlain, in the form

of terraces. These Quaternary clays form the basis of an enormous brick industry. Aside from these later clays the Devonian shales are employed at many localities for the manufacture of common brick, paving-brick, sewer-pipe, terra cotta. Cretaceous clays suitable for the manufacture of stoneware and fire-bricks are found in Staten Island and also on Long Island, where they are sometimes interbedded with other materials of a less refractory nature. In the central portion of the state the Salina shales are used to some extent in the manufacture of paving-brick and drain-tile. The New York clays are sometimes mixed with materials imported from other states in the manufacture of high-grade stoneware and terra cotta.

NORTH CAROLINA.

The clay deposits of North Carolina may be divided into—

Residual: kaolins, fire-clays and impure clays, and

Sedimentary: Coastal Plain clays, of Cretaceous or Tertiary age.

Sedimentary surface clays (for brick and pottery) are found mainly along the streams and lowlands in the Piedmont plateau and mountain counties.

Residual clays.—These occur in the western half of the state west of the line passing through Weldon, Raleigh and Rockingham. They form an almost universal mantle and vary in thickness from 3 to 20 feet. These impure residual clays are generally sandy and very porous, but with proper machinery and treatment they yield a good grade of brick.

The residual fire-clays found at Pomona and Grover are coarse-grained clays with much intermixed quartz and mica.

The kaolins are of special importance and of excellent quality, the most important being at Webster and west of Sylva.

Sedimentary clays.—The Coastal Plain deposits of North Carolina furnish the most extensive beds of clay to be found within the state. They have been classed as belonging to Cretaceous, Eocene and Pleistocene formations. The Potomac clays of the Cretaceous are exposed at Prospect Hall on the Cape Fear river, and the Eocene beds are well shown in railroad cuts at Spout Springs and Fayetteville.

Many clays suitable for the manufacture of brick and of pottery

are found underlying the river terraces farther inland, especially along the Catawba, Yadkin and the Clark rivers. Other sedimentary clays are well developed around Wilson, Goldsboro and Fayetteville.

NORTH DAKOTA.

The clays of North Dakota are of Cretaceous, Tertiary and Post-Tertiary age, and abound in many sections of the state. While they are suitable for a variety of purposes, they have thus far been but little worked.[16]

OHIO.

The principal centers of development of clays are in most instances the same as those which furnish the coal. The Sub-Carboniferous contains valuable deposits of flint-clay, which is mined at several points in Hocking county, and the Carboniferous conglomerate also contains several beds of fire-clay. Other beds occur over the Sharon coal in the Massillon sandstone, and are used for making sewer pipe and pottery. Another important bed underlies the lower Mercer limestone. Several important clay deposits occur in the lower Coal Measures, the beds varying in thickness from 6 to 30 feet. The Kittanning clay and shale is the most important in the state, and is the horizon which yields the well-known Mineral Point fire-clay. Other beds are found in the middle Kittanning and the lower and upper Freeport members of the Coal Measures.

In northern and western Ohio, the drift clays form an abundant supply of material for the making of common brick.

PENNSYLVANIA.

The most prominent deposits of Pennsylvania are the refractory shales and clays which occur in the Coal Measures, specially in the western portion of the state. The beds are often extensive, and occupy well-marked stratigraphic positions. Among the more important of these may be mentioned the Bolivar fire-clay, which occurs just under the Freeport upper Coal Measures. Another important bed of clay lies immediately under the Kittanning coal, throughout

[16] Report of commissioner of labor and agriculture, 1891–1892.

Beaver county. Another valuable bed is found near the top of conglomerate 12, and is mined in Cambria, Indiana and Beaver counties.

Large quantities of true kaolin are mined in Chester and Delaware counties and the mines at Brandywine Summit have been in operation for a number of years.

The brick clays are abundant and important in and around Philadelphia, where they belong to the Columbia formation; while the river terraces in the valleys of the Ohio and Beaver rivers are underlain by clay suitable for the manufacture of brick, terra cotta and stoneware.

SOUTH DAKOTA.

The clays of South Dakota are classed as brick, potters', fire-clays and fuller's earth.

Brick clay.—The material most commonly used for brick-making in South Dakota is some kind of loam such as that supplied by the loess in Union, Minnehaha and Moody counties. It is also thick in the high terraces along the Missouri and Cheyenne rivers, and in most of the country south of the White river, in the Laramie formation, in the northwestern counties of the state. Local beds are found underlying the flood-plains of the large streams.

Potters' clay.—Very plastic dark clays are said to abound in the Benton and the Pierre groups of the Cretaceous.

Light-colored clays abound in the White river beds, and in several horizons of the Paleozoic of the South Hills, which furnish clays that are probably adapted to the potter's purposes.

Fire-clays.—Extensive deposits of fire-clay occur in the Dakota formation which forms a rim around the Black Hills. This bed has been worked for several years, specially at Rapid City.

Fuller's earth.—Beds of this material have been reported from the vicinity of Fairburn, Custer county.

TENNESSEE.

The clay resources of this state are very similar to those of Kentucky.[17] The Carboniferous fire-clays and shales are abundant in the

[17] R. T. Hill. Mineral resources U. S. Geol. Survey, 1891.

eastern half of the state, and pottery clays of the Eocene and Lafayette formations are extensively developed in the western part. Around Chattanooga there are important factories for the manufacture of fire-brick and sewer-pipe.

TEXAS.

Brick-clays are abundant throughout the state. Many of the Tertiary clays are suitable for drain-tile and terra cotta, especially those of the Timber-belt and the Fayette formation, while fire-clays occur in the Timber-belt in Fayette, Henderson and Limestone counties, and in the Fayette, in Fayette county, but the last runs rather high in impurities.

The occurrence of clays is mentioned from various localities in the report on Grimes, Brazos and Robertson counties.[18]

VIRGINIA.

Brick-clays are extensively worked in the vicinity of Washington. Kaolin is said to occur in Augusta, Wythe and Cumberland counties, while there is the usual abundance of residual clays in those portions of the state not covered by Cretaceous and Tertiary deposits.

WISCONSIN.[19]

The clay deposits of Wisconsin are both residual and transported. The former are found chiefly in the driftless area, and have been derived from a variety of rocks, including granites, gneisses, shales and limestones. The latter are by far the most extensive, and the clay-working industry of the state is based chiefly on them. Many of the transported clays are lacustrine deposits representing the former extent of Lake Michigan; they occur therefore chiefly in the eastern part of the state.

The estuarine clays are found contiguous to the lacustrine beds and were formed at the same time, being of alluvial and glacial origin.

The glacial clays have a large areal extent, and occur mainly in the northern half of the state.

[18] 4th annual report Texas Geol. Survey.

[19] E. R. Buckley, The Clays and Clay Industries of Wisconsin. Bull. No. vii, pt. i, of Wisconsin Geological and Natural History Survey.

Residual clays, derived from Pre-Cambrian shales, are used at several points, and white-burning sedimentary clay, called "Kaolin," is found and mined in St. Croix county.

The clays in the northern, eastern and southern portions of the state are very calcareous; those of the southwestern and western parts are moderately so, while those in the central portion are low in lime.

The products at present manufactured from the Wisconsin clays consist chiefly of brick and tile, but clays suitable for other grades of ware are said to exist.

WYOMING.

All the clays of Wyoming that have any commercial importance occur in the sedimentary beds of the Jurassic and Cretaceous formations, but are also found to some extent in the Tertiary. The formations containing these clays are found flanking nearly all the mountain ranges in the state, but, with the exception of their being used for the manufacture of common brick in a few localities, very little development has occurred. All the fire-clay products now used in Wyoming are manufactured in Colorado. Pressed brick are also shipped into the state from various points.

The loess is utilized at a number of places in Wyoming.

The Technology of Clay-Working.

In this section it is proposed to treat briefly of the clays required for the different classes of clay products and of the types of machines commonly used.

On account of the number of inquiries which are sent to the office of the Geological Survey, it has been deemed proper to give a list of manufacturers of machines used in the various industries.

Structural Products.

Just as the character of bricks varies widely, whether they are common, pressed or paving brick, so do also the clays employed.

CLAYS FOR COMMON BRICK.

The requirements of such a clay are very loose, even the color of the burned material being seldom considered. It is, however, the

more impure clays that are ordinarily employed. These vary from very lean ones to those of high plasticity. Calcareous materials are also employed.

A clay to be used for the manufacture of common brick should be a red-burning one if possible, since there is more possibility of this burning dense at a comparatively low temperature and thus avoiding the use of too much fuel. Most brick-clays are burned to about cone 05, and at this temperature the clay commonly shows incipient fusion.

Good brick-clays should burn hard at a temperature of not over 2000° Fahr., namely, at cone 1, or preferably lower. This means the presence of sufficient fluxing material to bind the clay grains together into a hard body when burned. Large sand grains and pebbles are undesirable as they tend to make the product porous and weak. The best results are commonly obtained with clays running in from 5 to 7 per cent of ferric oxide. The residual limestone clays are often ferruginous, and those derived from the gabbros of the crystalline area are often highly so, too much in fact for the production of a really good brick.

Calcareous clays are not infrequently used for brick-making, sometimes from choice, at others from necessity. In Maryland their distribution is more or less restricted to the Pleistocene formations in the southeastern part of the State, on the eastern side of Chesapeake Bay. These materials may be found to serve better for making Portland cement than bricks.

The undesirable behavior of lime is its effect on the firing qualities of the clay, by bringing the points of incipient fusion and viscosity too close together, as explained under lime (p. 242). This, therefore, interferes with the production of a vitrified or a good hard brick, and yet with care a very fair building brick can be made from calcareous clays, provided the lime be finely and evenly divided, for lumps of lime carbonate are very likely to cause bursting of the burned brick. Most of the common brick of cream or yellowish white color are made from calcareous clays. In former years most of the pressed brick seen were made from calcareous clays, but semi-refractory clays are now preferred.

When brick-clays contain pebbles they are sometimes dried and screened or put between rollers.

Sand is often added to brick-clay since it tends to lower the plasticity and decrease the shrinkage in burning. The quantity commonly added averages about 30 per cent, but it is not always necessary. The coarser the sand the more marked will be the effect on the shrinkage. Rounded sand grains are also more desirable than angular ones for the reason that angular grains serve like wedges in the drying and may produce cracks in the shrinking clay.

In the burning and drying of brick-clays great precautions have to be taken with highly plastic materials, since there is much danger of warping or cracking. Similarly, great caution must be observed with very fine-grained clays.

The following figures give the maximum, minimum and average percentage of the different constituents in brick-clays, the figures being deduced from a number of analyses from different parts of the country:

	MAXIMUM.	MINIMUM.	AVERAGE.
Silica	34.35	90.877	49.27
Alumina	22.14	34.00	22.77
Ferric oxide	.126	15.00	5.311
Lime	.024	13.20	2.017
Magnesia	.02	11.03	2.66
Alkalies	.17	15.32	2.768
Water	.05	13.60	5.749
Moisture	.17	9.64	2.505

The following tests indicate the physical character of brick-clays used in different parts of the country:

Quaternary brick-clay from the Hudson Valley at Roseton, New York. Air-shrinkage, 5 per cent; incipient fusion at cone 05; and vitrification at cone 04, with a total shrinkage of 14 per cent; viscosity at cone 01. Tensile strength from 75 to 93 lbs. per square inch.

Quaternary clay from Canandaigua, New York, upper layer in bank. 22 per cent of water required to work up to a plastic mass; air-shrinkage, 8 per cent; incipient fusion at cone 05, with total shrinkage of 15 per cent; vitrification at cone 03, with total shrinkage of 16 per cent; viscosity at cone 8. This clay burns red.

Lower or buff-burning clay from same locality. 18.5 per cent of water required to temper it. Air-shrinkage, 6 per cent; vitrification at cone 1, with 14 per cent shrinkage, and viscosity at cone 2. Tensile strength about 95 to 110 lbs. per square inch.

Brick-clay of Glacial age, Southhold, Suffolk county, New York. A very plastic clay requiring 40 per cent of water. Air-shrinkage, 8 per cent; incipient fusion beginning at cone 08; total shrinkage 9 per cent. Vitrification at cone 1 with total shrinkage of 16 per cent. Viscosity at cone 4.[20] Clay burns deep red. Tensile strength 133 to 140 lbs. per square inch.

Brick-clay from Clippert Bros.' yard, Detroit, Michigan. A calcareous clay. 24 per cent of water required to work it up, the briquettes having air-shrinkage of 4 per cent. At cone 05 total shrinkage 6 per cent; clay burns red; at cone 01, incipient fusion occurs with a total shrinkage of 14 per cent, the bricklet being buff; vitrification occurs at cone 2, and the clay becomes viscous at cone 4. Its tensile strength is 125 lbs. per square inch.

Lower clay from the same locality. A very plastic blue clay requiring 26 per cent of water. Incipient fusion occurs at cone 05, with a total shrinkage of 9 per cent. Vitrification at cone 1 with a total shrinkage of 15 per cent; viscosity at cone 5. Tensile strength 175 to 190 lbs. per square inch. It is found difficult to work this clay alone.

Brick-clay from upper bed of Penniman's clay-bank, Emma, North Carolina. 20 per cent of water works it up into rather a plastic mass with an air-shrinkage of 9 per cent. Up to vitrification the total shrinkage is 13 per cent; the air-dried briquettes ranged from 63 to 80 lbs. tensile strength per square inch. Incipient fusion at 2000° Fahr., vitrification at 2200°, and viscosity at 2400° Fahr.

Brick-clay from Poe Bros.' yard, near Fayetteville, North Carolina. 28 per cent water required to work it up into a very plastic mass. Air-shrinkage, 8.5 per cent; total shrinkage up to vitrification, 13.5 per cent. Tensile strength averaged 144 lbs. per square inch. Incipient fusion at 1900° Fahr., vitrification at 2050°, and viscosity at 2200° Fahr. The clay burns deep red.

[20] New York State Museum, Bulletin 35.

Residual brick-clay near Greensboro, North Carolina. 28 per cent of water required to work it up. Air-shrinkage, 9 per cent; total shrinkage up to vitrification, 15 per cent. Average tensile strength, 85 lbs. per square inch. Incipient fusion at 2050° Fahr., vitrification at 2250°, viscosity at 2450°. Clay burns red.

An alluvial brick-clay from Kirkpatrick's yard, Greensboro, North Carolina. 30 per cent of water works it up into a very plastic mass. Air-shrinkage, 11 per cent; total shrinkage up to vitrification, 16 per cent. Average tensile strength 220 lbs. per square inch. Maximum of 232 lbs. Incipient fusion at 1900° Fahr., vitrification at 2100°, and viscosity at 2300°. It burns to a dense red body, but requires slow-heating to prevent cracking.[21]

Brick-clay, Jefferson City, Missouri. A lean clay requiring 17.2 per cent of water to temper it. Air-shrinkage, 5.7 per cent. Shrinkage in burning, 4.3 per cent. Incipient fusion 2000° Fahr., vitrification at 2000°, and viscosity at 2300°. Average tensile strength 131 lbs. per square inch.

Brick-clay, Kansas City, Missouri. 18.4 per cent water required, giving a lean mass. Air-shrinkage, 5.1 per cent; total shrinkage in burning, 10.8 per cent. Incipient fusion at 2000° Fahr., vitrification at 2200°, and viscosity at 2200°. Average tensile strength 151 lbs. per square inch. This is a loessoid clay.[22]

Brick-clay (loess) from Denver, Colorado. A lean clay taking 14.5 per cent of water to work it up. Air-shrinkage, 6 per cent; total shrinkage in burning, 9 per cent; air-dried briquettes average tensile strength of 55 lbs. per square inch. Incipient fusion at 2000° Fahr., vitrification at 2100°, viscosity at 2200°. Clay burns red.

Brick-clays are not restricted to any geological formation, but the deposits worked are in every case surface ones, for, since the price of the product is so low in most states only those materials can be used which can be cheaply mined.

[21] North Carolina Geol. Survey, Bulletin 13.
[22] Missouri Geol. Survey, vol. xi.

ANALYSES OF BRICK CLAYS.

State and County.	Town.	Remarks.	Silica. Combined.	Silica. Free.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water. Combined.	Water. Free.	Miscellaneous.	Firm Names, Authority or Analyst.
Alabama:													
Greene	Gainesville ...	......	71.17		18.44	2.77	.25	.44	.9	....	....	Loss 6.03	Ark. Geol. Sur. 1888, p. 107.
Little River ...	Williamslake .	......	58.24		13.22	9.25	4.55	4.19	3.22	....	....	Loss 8.96	Ibid. p. 296.
Poinsett	Harrisburg ...	......	81.37		8.52	2.88	.44	.5	2.4	....	....	MnO_2 1.01, Loss 2.88	Ibid. 1889, 2; 85.
Tuscaloosa....	....	Pinkish clay. Tuscaloosa Cretaceous..	68.108		10.858	14.471	....	....	....	7.085	....	....	Ala. Geol. Sur. Report on Valley Region, p. 180.
California:													
Placer.........	Lincoln	......	44.82		34.54	1.86	1.55	.96	4.74	....	9.64	Loss .44	Cal. State Min. 11th Rep't.
Colorado:													
Pueblo	Pueblo.......	......	61		35	.25	....	....	....	....	3.75	....	Stand. Fire Brick Co.
Georgia:													
Bartow	Cartersville ..	Clay	58.63		20.47	8.58	....	1.71	1.98	6.83		....	Ga. Geol. Sur. 1893, p. 286.
Floyd	Rome	Surface clay..	67.8		13.82	5.74	....	.81	2.55	7.6		TiO_2 1.67	Ibid. p. 287.
Illinois:													
Lasalle	Lasalle..... ..	Red Clay.....	62		18.1	9.11	....	....	....	....	....	SO_3 .1, Loss 5.66	La Salle Pressed Brick Co.
Peoria........	Peoria	......	72.1		16.1	3.3	.61	.77	2.9	3.86		....	Peoria Brick Co.
Indiana:													
Hamilton	Noblesville...	Clay	74.33		12.94	5.2	.666	.861	....	5.97		....	H. Teller.
Marion	Indianapolis..	Terra-cotta...	59.08		31.3	.5	.8	.6	....	....	....	7.72	Indianapolis Terra-Cotta Co.
Parke	Montezuma...	......	54.53		24.66	7.46	.37	1.28	...	10.7		....	S Schumaker.
Warren.......	Williamsport.	Clay	45.22		25.98	13.6	.336	.21	....	15.2		....	S. Field.
Vigo	Terre Haute ..	Used for brick, but good for vitrified ware	66.11		13.78	5.35	1.67	1.78	3.26	6.38	9.25	....	Ind. Geol. Sur., xx, p. 76.
Iowa:													
Clay..........	Spencer......	Altered loess .	52.42		13.04	6.24	7.98	2.24	8.08	4.06	2.67	CO_2 7.57	G. C. Patrick, anal. from Ia. Geol. Sur.

ANALYSES OF BRICK CLAYS—Continued.

State and County.	Town.	Remarks.	Silica. Combined.	Silica. Free.	Alumina.	Ferric Oxide	Lime.					Miscellaneous.	Firm Names, Authority o· Analyst.
IOWA—Cont.													
Guthrie.......	Guthrie Centre	Brick and tile loessclay. W E. Barry yard	68 62		14.98	4.16	1.48					MnO .64	G. C. Patrick, anal. from Ia. Geol. Sur.
Warren	Indianola	Loess clay, Plastic	63.31		16.57	4.06	1.11	1.1	3.16	6.89	3.76	MnO .49	Ibid.
	Lime Creek...	Mason City shale	54.64		14.63	5.69	5.16	2.9	5.89	3.74	.85	MnO .76 CO_2 4.8	Ibid.
KANSAS:													
Greenwood....	Flintridge....	....	58.2		29.8	a5.4	6	....	....	.6		....	Crossley. Analyses of Clays.
KENTUCKY:													
Ballard	Wickliffe....	Yellow clay...	44.84		22.83	20.35	.101	.138	...	11.741		....	Ky. Geol. Sur. ch. Rept. A, pt. 3, No. 2568.
LOUISIANA:													
New Orleans..	......	Sandy clay ...	16.36	48.27	14.07	4.06	....	1.67	6.97	7.06	....	....	J. A. Blaffer & Son.
MAINE:	Farmington ..	Sandy clay ...,	63.69		17.02	10.18	.97	....	4.02	4.15		....	A. J. S. (3), xxxiv, p. 407.
MASSACHUSETTS:													
Berkshire	Clayton	Brick and terra cotta clay...	50		44	a1.07	.024	....	1.24	....	....	....	White Brick and Terra-Cotta Co.
Middlesex.....	W. Cambridge	Glacial clay ..	48.99		28.9	3.89	7.1	3.66	4.73	3.31		....	J. Card, anal.
MICHIGAN:													
Jackson	Springport township	G. H. Wolcott's yard........	52.26		22.95	8.15	4.48	1.32	....	10.56	....	....	Mariner & Hoskins, anal.
Kent	Grand Rapids	Clay	56.7		25.95		1	.74	5.54	6.07		....	S. P. Sharpless, anl.
MINNESOTA:													
Blue Earth....	Mankato	Clay shale....	70.1		16.99	trace	....	....	10.69	1.98		SO_3 .23	Minn. Geol. Sur. Final rep't, p.488.
Hennepin	Minneapolis ..	......	60.31		23.77	7.96	2.5	1.75	2.42	....	....	....	A. Humphreys.
MISSISSIPPI:													
	Clingscales...	......	90.877		2.214	.126	.14	trace	....	6.98		....	Hilgard. Geol. Miss. 1890.

ANALYSES OF BRICK CLAYS—Continued.

State and County.	Town.	Remarks.	Silica. Combined.	Silica. Free.	Alumina.	Ferric Oxide.	L	Magnesia.	Alkalies.	Water. Combined.	Water. Free.	Miscellaneous.	Firm Names, Authority or Analyst.
MISSOURI:													
Cole..........	Jefferson City.	For red brick.	74.39		12.03	4.06	1.5	1.52	3.01	3.17	....	....	Mo. Geol. Sur. xi; p. 563.
Jackson	Kansas City ..	For red brick.	72		11.97	3.51	1.8	1.12	3.25	6.42	....	....	Ibid. p. 564.
St. Louis	St. Louis.....	Alluv. Mo. riv. dep's't ...	51.68		23.65	6.63	1.4	.2	2.23	8.75	5.14	....	
MONTANA:													
Deerlodge	Blossburg....	......	72		17	2	2	3	....	....	....	....	Mullan Br'k T. Co.
NEBRASKA:													
Douglas C'y...	Omaha.......	Red clay	72.53		12.05	4.28	1.03	1.2	3.1	3.36	2.45	....	From Omaha Hyd. Pressed Brick Co.
Douglas C'y...	Omaha.......	Buff clay.....	79.5		11.61	2.57	....	.68	1.29	3.5	.85	....	Ibid.
NEW JERSEY:													
Middlesex.....	Sayreville....	......	28.3	27.8	27.42	2.68	....	.18	2.71	6.6	2.9	....	Sayre & Fisher.
Middlesex.....	Cheesequake Creek	Brick clay....	28.3	28.7	21.5	4.31	....	.82	1.9	8.04	1.7	SO_3 1. CO_2 3.8	N. J. Clay Report, 1878, p. 317.
NEW YORK:													
Clinton.......	Plattsburg ...	Red clay	65.14		13.38	7.65	2.18	2.36	8.51	....	....	....	H. T. Vulté, anal.
Onondaga.....	Warners	Clay shale....	57.79		16.15	5.2	2.73	4.67	5.33	....	4.5	CO_2 3.42	Bull. 35 N. Y. S. M.
Ontario..	Canandaigua .	Quatern'y clay	45.12		12.76	5.44	a23.32	5.42	....	....	....	...	Ibid. p. 891.
Orange	Roseton.. ..	Gray clay	55		34.54		5.33	3.43	.48	....	....	....	Ibid. p. 891.
Suffolk	......	Glacial clay ..	59.05		22.11	6.54	2.19	2.64	6.22	....	....	....	Ibid. p. 891.
Tompkins.....	Newfield	Clay	51.3		12.21	3.32	11.63	4.73	4.33	....	....	Org. 1.85	
NO. CAROLINA:													
Buncombe	Emma	Upper clay Penniman's yard........	66.27		19.95	3.16	.2	.32	1.85	6.17	1.15	FeO.67	Bull. 13 N. Carolina Geol. Sur. p. 104.
Buncombe	Emma	Lower clay...	70.66		17.21	3.44	.1	.07	2.45	.05	.8	....	Ibid. p. 105.
Cumberland...	Fayetteville ..	Brick clay.... E. A. Poe's Yd.	64.93		17.08	5.57	.43	.59	3.85	6.58	2.48	....	Ibid. p. 110.
Cumberland...	Fayetteville ..	Tough clay. E. A. Poe's yd.	58.17		20.1	7.43	.6	.77	2.6	7.34	3.23	....	Ibid. p. 111.
Guilford	Greensboro...	Residual clay. Greensboro B. & T. Co...	56.81		20.62	6.13	.65	.58	4.47	8.6	1.64	....	Ibid. p. 114.

State and County.	Town.	Remarks.	Silica. Combined.	Silica. Free.	Alumina.	Ferric Oxide.							Firm Names, Authority or Analyst.
N. C'LINA—Cont.													
Halifax	Roanoke Rpds.	......	67.55		18.16	8.54							Ibid. p. 117.
NORTH DAKOTA:													
Grand Forks	Grand Forks	......	51.27		9.33	3.53							Report Labor Bur. 1891.
OHIO:													
Lawrence	Coal Grove	B. and t. clay	56.9		28	1.5							Forestdale B. & T. Works.
Trumbull	Doughton	Semi-plastic blue-gray clay	63.69		23.91	3.57							
PENNSYLVANIA:													
Beaver	New Brighton	Terrace clay	67.78		16.29	4.57							1897 Report Pa. State Coll.
	Kittaning	Soft brown shale	58.31		24.54	8.75							1897 Report Pa. State Coll. p. 123.
	Charleroi	Red clay	56.32		21.44	9.92							Ibid. p. 131.
TENNESSEE:													
Scott	Robbins	Clay	70.57		15.19	7.97							Clay Worker, Dec. 1893.
TEXAS:													
Harrison	Marshal	......	71.		20.2	2.2							2d Report Iron Ore Dist. 1890.
Rusk	Henderson	.....	64.4		24.17	3.23							Tex. Geol. Sur. 1890, p. 219.
WASHINGTON:													
Pierce	Tacoma	White clay	62.43		18.79	4.2							L. J. Clark.
WEST VIRGINIA:													
Marshal	Moundsville	......	74.62		16.01	2.86							Mound City B'k Co.
Monongalia	Morgantown	Clay near riv.	73.88		12.73	5.78							A. R. Whitehall, anal.
WISCONSIN:													
Milwaukee	Milwaukee	Clay	38.22		9.75	2.84	13.24	d15.88	2.81	2.30		$FeCO_3$ 1.16	Geol. Wis. ii, p. 226.
Milwaukee	......	From the Chase B'k Co	38.07		9.46	2.7	15.84	8.5	2.76	....	2.49	CO_2 20.46	

CLAY FOR PRESSED BRICK.

Here care must be taken, from the selection of the clay, through its various manipulations, up to the completion of the product, for, since pressed-brick are used for finish and decoration, form and color are all-important in the ware. This means, therefore, that clays must be chosen which will shrink uniformly and to only a small degree in burning; and furthermore, the coloring matter must be uniformly distributed through them. They should also be free from soluble salts, which are likely to cause discoloration in the finished product.

Many different grades of clays are employed in the manufacture of pressed-brick, but, except for producing red shades, manufacturers are working more and more towards the use of semi-refractory buff-burning clays. The object of this is two-fold, viz., they can be burned to a hard product, and the buff color makes an excellent ground for the mixture of artificial coloring substances.

Variations in any one shade are brought about by varying the intensity of the fire.

The requirements of clays for paving-brick are discussed further on.

In the following table are given the analyses of a number of pressed-brick clays showing the range of materials now used.[23]

COMPONENTS.	SHALE, KANSAS CITY, MO.	WHITE CLAY, GROVER, N. C.	FRONT BRICK CLAY, SAYREVILLE, N. J.
Silica	55.75	68.28	56.10
Alumina	21.16	18.83	27.42
Ferric oxide	5.69	2.60	2.68
Lime	3.25	.70	....
Magnesia	2.84	.13	.18
Alkalies	3.02	2.29	2.71
Water	8.45	6.47	6.00
Moisture	....	.76	2.90
Titanic acid	....	.27	1.00

METHODS OF BRICK MANUFACTURE.

The steps in the manufacture of clay into bricks are usually the same whether common or pressed-brick are to be made. The differences lie in the forms of machinery employed and in the care with

[23] H. Ries, Min. Indus., vol. ix, p. 106.

which the process is carried out. The stages are those of preparation, molding, drying, burning.

PREPARATION.

Clays can seldom be charged into the molding machine directly as they come from the mine. Some are too hard or too dry and need softening up, and others need drying out. The preparing of the clay can be done by either natural or artificial methods.

Weathering is the natural way and consists in spreading the clay mass out in a thin layer, thus exposing it to wind, frost and rain. This is slow but thorough and has the effect of disintegrating the clay quite thoroughly. Nodules of carbonate of iron (siderite) or clay iron-stone and pyrite are both changed to limonite in this process and are readily seen and picked out. There are times, however, when soluble sulphates may be formed through the decomposition of pyrite.

The weathering of clay is relied on by the fire-clay manufacturers in Allegany county. Some pressed-brick manufacturers also resort to this mode of treatment, the several clays which they use being spread out several layers deep and left for several months. If the clay contains much organic matter the decomposition of the latter sets free carbon dioxide, which in escaping aids in the disintegration of the clay lumps. The time clay is allowed to weather varies from a few months in pressed-brick manufacture to several years for glass pot clays.

Artificial methods are usually relied on entirely for properly preparing the clay. The machines used fall into two types, viz., crushing machines and mixing machines.

Crushing Machines.—All of these treat the clay in a dry or nearly dry condition and most of them are for the purpose of disintegrating hard clays such as shale.

Jaw Crushers.—These are well-known machines and their chief application in the clay-working industry lies in using them for the preliminary breaking of very hard shales so that they can be further broken down in a disintegrator or pan-crusher. There are several different makes, but their essential principle is the interaction of two

movable jaws, closer together at the lower ends than at their upper ones. These crushers are strong and effective. As examples of these may be mentioned the Blake Crusher, New Haven, Connecticut; the Sturtevant Roll Jaw Crusher, Jamaica Plains, Massachusetts (Fig. 17); The Gates Crusher, Gates Iron Works, Chicago, Illinois.

Dry-pans.—The dry-pans which are often used to pulverize shale consist of a circular pan in which two iron wheels revolve on a horizontal axis, being made to turn by friction against the bottom of

FIG. 17.—Sectional cut of Sturtevant roll jaw crusher.

the pan, which is rotated by steam-power (Fig. 18). The wheels weigh from 2000 to 5000 pounds each, and the bottom of the pan is made of removable, perforated plates, the rectangular openings in which are usually from 1/16 to 1/4 inch in width.

The capacity of a dry-pan depends of course on the size of the screen meshes and dryness or softness of the clay or shale. For a medium shale, which is fairly dry, it is possible to grind eight tons per hour through an $\frac{1}{8}$-inch screen, and about 12 tons through a $\frac{1}{4}$-inch. Two scrapers are placed in front of the rollers to throw the material in their path.

Dry-pans are usually made from 6 to 9 feet in diameter. For a

nine-foot pan with the grinding rollers 48 inches in diameter and 12 inches face, the total weight of machine would be about 40,000 pounds; while the weight of the two rollers with their shafts and

FIG. 18.—Dry-pan used for pulverizing shales and clays.

boxes is about 13,000 pounds. From 12 to 16 horse-power is required to operate them.

Among the manufacturers of dry-pans are the Chambers Brothers Company, Philadelphia; American Clay-Working Machinery Company, Bucyrus, Ohio; Chisholm, Boyd & White. Chicago, Illinois; Frost Manufacturing Company, Galesburg, Illinois.

Disintegrators.—The principle of these consists of having several drums, or knives, on axles revolving rapidly within a case and in opposite directions. The lumps as they enter the machine are thus thrown violently back and forth between the drums and against each other, making the disintegration rapid and complete. In the Steadman disintegrator there are several concentric drums (Fig. 19). In

FIG. 19.—Steadman disintegrator for breaking up lumpy clay.

the Williams pulverizers there are two axles containing adjustable arms which move rapidly in opposite directions and pass between each other. Disintegrators are often used for preparing clay or shale for dry-press machines. They have a large capacity but also require much power to operate. According to their size they can pulverize from 8000 to 28,000 pounds of material such as shale or gypsum in one hour. They require from 2½ to 4 horse-power for every ton of material pulverized in one hour. Disintegrators are obtainable from

the Steadman Company, Anderson, Indiana; Simpson Manufacturing Company, Chicago, Illinois; Williams Patent Crusher & Pulverizer Company, St. Louis, Missouri.

The American Clay-Working Machinery Company, of Bucyrus, Ohio, also make disintegrators of 36, 40, 44 and 50-inch diameters. They make from 425 to 750 revolutions per minute, and require from 15 to 40 horse-power to drive, and weigh from 5500 to 15,000 pounds, according to size.

Rolls are used by many manufacturers of clay products for break-

FIG. 20.—Disintegrating rolls for grinding clay.

ing up clay or shale, and when run on dry material are far more effective as a disintegrating machine than when run on wet. The surfaces of the rolls are smooth, corrugated or toothed, and the two rolls revolve at differential velocity from 500 to 700 revolutions per minute. They are manufactured by nearly all manufacturers of brick machinery. Fig. 20 shows one made by Chambers Brothers, of Philadelphia, Pennsylvania; other types are made by the American Clay-Working Machinery Company, Bucyrus, Ohio; J. W. Hensley, Indianapolis, Indiana, and a pulverizing machine is made by the Raymond Brothers Impact Pulverizer Company of Chicago, Illinois.

In nearly every case where one of the machines above mentioned has been used in preparing the clay it had to be put through a wet

FIG. 1.—RING-PIT GENERALLY USED IN MARYLAND.

The Friedenwald Co.

FIG. 2.—PALLET RACKS FOR DRYING SOFT-MUD BUILDING BRICK.

process in a second machine, which is commonly referred to as *tempering*. The tempering process consists in getting the clay mixed up to the proper condition for molding, usually by mixing it thoroughly with water. In some cases the tempering is simply done; in others it is carried out very carefully, depending on the nature of the product. The machines which may be used are soak-pits, ring-pits, pug-mills.

Soak-pits.—These, though used for many years, are rapidly disappearing and they are now seldom seen except at small brick-yards and need but short mention. They are built immediately behind the molding machine. The clay, and also sand if it is to be added, are dumped into the pit in the afternoon, water poured on, and the mass allowed to soak over night. This process simply wets the clay up, but accomplishes little or no mixing. The following morning the clay is shoveled into the molding machine.

Ring-pits.—These are now used at many yards where common brick are manufactured, and are far more efficient than soak-pits. Such a pit is circular, 25 to 30 feet in diameter and 3 to 5 feet deep, and lined with boards or brick. In this pit there revolves an iron wheel, 6 feet in diameter, and so geared that it travels around the pit; it also moves back and forth between the center and circumference, thus cutting into and mixing all parts of the clay. The tempering occupation requires several hours and the pit holds enough clay for 25,000 or 30,000 brick. Two ring-pits are often operated in conjunction with one molding machine, so that while the clay is being shoveled out of one pit the second pit can be tempering a supply for the next day. Plate XXV, Fig. 1, shows the type of ring-pit used at the brick-yards around Baltimore.

Ring-pits are cheap as compared with pug-mills, but smaller in output. They are operated by either steam or horse-power. They are made by a number of firms, among them Chambers Brothers, Philadelphia, Pennsylvania; Geo. Carnell, Philadelphia, Pennsylvania.

Pug-mills are among the most thorough tempering machines when made of sufficient length. They differ from the ring-pit in having

a larger capacity and being continuous in their action. The form of a pug-mill is that of a semi-cylindrical trough, 6 to 10 feet long, in which there revolves a shaft bearing knives, set spirally around it, or a worm screw 6 or more inches wide (Fig. 21). The clay and water are charged at one end and the knife-blades not only cut it up, but also mix it, while at the same time it is moved along to the other end of the trough, from which it is discharged. Pug-mills may be closed or open on top. The speed of the clay through the machine is regulated by varying the angle of the knives on the shaft. Pug-mills, according to their size, will temper enough clay for from 25,000 to 60,000 brick in 10 hours. They take up less room than ring-pits

Fig. 21.—Pug-mill used for tempering clay.

and do not require as much power to operate. When made too short they are not likely to give the clay sufficient mixing.

Formerly pug-mills were used only in connection with stiff-mud machines, but now they are often used in conjunction with soft-mud ones. Occasionally a double form of pug-mill is used.

The lengths of a pug-mill may vary from 4 up to 14 feet.

Pug-mills are manufactured by American Clay-Working Machinery Company, Bucyrus, Ohio; Chambers Brothers, Philadelphia, Pennsylvania; J. W. Hensley, Indianapolis, Indiana; Leader Manufacturing Company, Decatur, Illinois.

MOLDING.

The method employed for molding bricks has much to do with their shape, size and durability. The processes of molding now

recognized are the soft-mud, stiff-mud, dry-press and semi-dry press. In every case except the first the machines are operated by steam-power.

Soft-mud process.—The general principle of this process consists in mixing the clay with water, and also sand if necessary, to the consistency of a soft mud, after which it is pressed into the molds. At many small yards the clay after tempering is forced by hand into wooden molds.

The modern soft-mud machine consists usually of an upright box of wood or iron, in which there is a vertical shaft bearing several knives horizontally. Attached to the bottom is a curved arm which forces the clay into the press-box. The molds, which are sanded before using to prevent the clay sticking, are put into the machine at the rear side and automatically shoved forward under the press-box. Each mold has six divisions, and as it comes into position under the press-box the plunger descends and forces the soft clay into the molds. The filled mold then moves forward while an empty one moves in to take its place. Since the upper surface of the clay is rough it is necessary to scrape or "strike" off the top of the mold by means of a scraper. Soft-mud bricks, therefore, show one rough face and five smooth, sandy ones, due to the sand from the mold adhering. Soft-mud machines have a capacity of about 22,000 brick per day of 10 hours, 6 brick being molded at a time. Four laborers are commonly required to tend a machine. The molds are sometimes sanded by hand but more frequently by a machine consisting of a barrel on which the molds are fastened to form the sides. Sand is put inside and as the barrel revolves on its horizontal axis the sand falls into the compartments of the molds. As soon as one mold is removed another requiring sanding is put in its place.

The soft-mud process was the first method of molding employed and still stands in great favor with many manufacturers. It produces a brick of very homogeneous structure and one that seldom is affected by frost action. It is also adapted to a wide range of clays. The disadvantages are that it does not produce a smooth product with sharp edges. This defect was overcome when pressed-brick

were desired by repressing the product. Figure 22 illustrates a soft-mud machine and Fig. 23 shows plan of soft-mud plant.

Several forms of soft-mud machines are manufactured but the principle of them is the same. Among them may be mentioned Martin Brothers, Lancaster, Pennsylvania; American Clay-Working Machinery Company, Bucyrus, Ohio; W. E. Talcott & Company, Croton-on-Hudson, New York; J. W. Hensley, Indianapolis, Indiana.

FIG. 22.—Martin soft-mud machine for molding brick.

Molds and sanding machines are made by J. W. Hensley, Indianapolis, Indiana (Monarch); American Clay-Working Machinery Company, Bucyrus, Ohio (Eagle Horse-Power Machine).

Stiff-mud process.—In this the clay is tempered quite stiff and forced through a rectangular die in the form of a bar which is then cut up into bricks. The machine now commonly used is known as the Auger machine. Its general form is that of a cylinder closed at one end but at the other tapering off into a rectangular die whose cross-section is the same as the end or side of the brick. Within the cylinder, which is set horizontally, is a shaft carrying knife-blades

set at an angle, while at the die end is a tapering screw. The die is sometimes heated by steam or lubricated by oil on the inner side,

FIG. 23.—Plan of a soft-mud brick plant.

either being done to facilitate the flow of the clay through it. The clay and water are charged through a hopper into the end of the

cylinder farthest from the die and is mixed up by the revolving blades and at the same time moved forward until it is seized by the screw and forced out through the die. It will thus be seen that the clay undergoes a large amount of compression and that considerable power is required to force it through the die (Fig. 24).

Auger machines are either end-cut or side-cut, depending on whether the area of the cross-section of the bar of clay corresponds to the end or side of a brick and consequently the mouth-pieces vary in size and shape at cross-section, according to the kind of brick or other product.

When a bar of clay emerges from a rectangular opening there is more friction at the corners than in the centre of the bar or on the sides, and for this reason the internal form of the mouth-piece should be such that a sufficient quantity of clay will be forced toward the corner of the die to preserve an equal velocity in all portions of the emerging clay stream.

The effect of the screw, together with the difference in velocity between the central and outer positions of the clay stream is to produce a laminated structure in the brick. Plastic clays laminate more than lean ones, and even the same clay may laminate more with one die than another. Irregularity of clay supply may be another cause. In common brick laminations are less harmful than in paving-brick and they may at times be obliterated by repressing or thorough burning. The Auger machine is probably more extensively used at the present day than other forms, especially for the making of paving-brick. It has a large capacity, 60,000 brick being not an unusual output for 10 hours. The capacity of the Auger machines is often increased by causing two or even three streams of clay to issue from it at the same time, and some machines are said to have reached a capacity of 150,000 bricks in one day.

The principal of the stiff-mud machine is an excellent one if properly used, but from an improper use of it many failures have resulted. Thorough pugging is highly essential, and that which it gets in the machine is not by any means always sufficient. Small machines, having a very short cylinder, are put on the market and many small

manufacturers, tempted by their cheapness, have used them, thinking that the clay can be run through them without any preliminary treatment, except possibly a pair of rolls to break up the lumps. If the lumps are moist the rolls simply flatten them out and, being sometimes of different color than the rest of the clay used, they retain their individuality in the brick. Many stiff-mud brick made some years ago in Baltimore and used for pavements in some parts of the city plainly show this.

Stiff-mud bricks usually have four smooth faces and two rough ones, due to the drag of the cutting wires, for as the bar of clay

FIG. 24.—Stiff-mud machine for molding brick.

issues from the machine it is received on the cutting tables. This carries a frame bearing a series of parallel wires. When the bar of clay has issued to a sufficient distance the frame with wires is drawn across the table, cutting through the bar. In some machines the bar is stopped for doing this, in others the cutting is done without stopping the bar. When the former method is followed the bricks are removed onto a pallet, but with the latter the bricks are often received onto a belt, traveling at a greater speed than that at which the bar issues from the die. The effect of this is to separate the bricks. Figure 24 shows the general construction of a stiff-mud machine.

The stiff-mud process is adaptable mainly to clays of moderate plasticity which will dry in a reasonable time. As the clay flowing through the die requires much tenacity to escape tearing, very

silicious clays are not desirable; neither must the clay be too dry in order to avoid the same trouble. The capacity of stiff-mud machines varies greatly and their use is extending. They are used for common, pressed and paving-brick.

Manufacturers: Chambers Brothers Company, Philadelphia, Pennsylvania; American Clay-Working Machinery Company, Bucyrus, Ohio; Kells Brothers, Adrian, Michigan; Wallace Manufacturing Company, Frankfort, Indiana; Leader Manufacturing Company, Decatur, Indiana.

Dry-press process.—This method, owing to its peculiarities, is restricted to the production of front-brick and yet it is not used in

FIG. 25.—Side cut, automatic cutter.

this direction to the exclusion of all others. The clay after being dug is commonly stored in sheds to dry as much as possible, and when ready is broken up either in a disintegrator or wet-pan before passing to the screen. This screen is usually set at a high angle, about 45°, and the material which is fine enough to pass through goes to the hopper of the pressing machine while the tailings fall back into the pulverizer.

The molding machine consists of a steel frame of varying height and heaviness. About 3 feet up from the ground is the delivery table, into which the press-box is sunk. Connected with the hopper by means of canvas tubes is the charger which slides back and forth on the table. It is filled on the backward stroke and on its forward

stroke lets the clay fall into the mold-box. The charger then recedes to be refilled and at the same time a plunger comes down, pressing the clay into the mold. As the upper plunger descends a lower plunger which forms the bottom of the mold moves upward so that

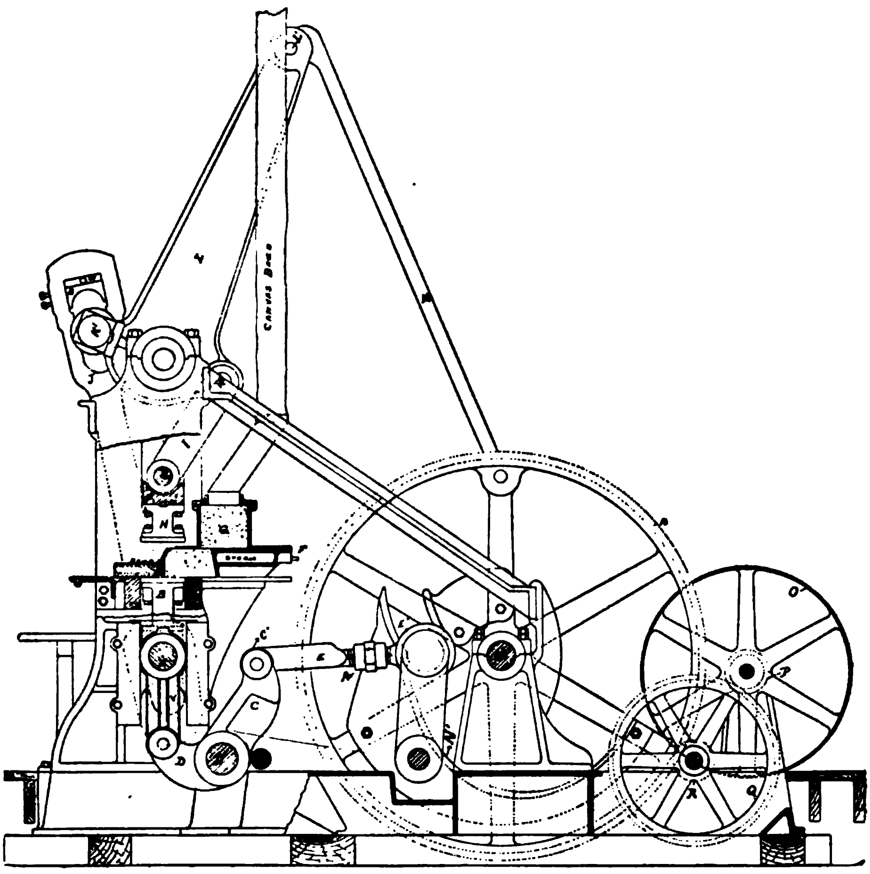


FIG. 26.—Section of Simpson dry-press brick machine.

the clay receives pressure from above and below. The upper plunger then rises and the lower plunger ascends till the lower surface of the charger comes forward, shoving the green brick out on the table, the lower plunger drops and the mold-box is once more filled with clay. The faces of the mold are of hard steel, heated by steam to prevent adherence of the clay. Air-holes are also made in the

dies to permit the air to escape from between the clay particles. If this were not done the air would be compressed and when the pressure was released, in its efforts to escape, there would be danger of splitting the brick.

The pressure from above is usually applied by means of a toggle-

FIG. 27.—Boyd dry-press brick machine.

joint. One to six bricks are molded at a time, according to the size of the machine.

At several works in the country a hydraulic dry-press machine is used. In this the pressure is produced by a pair of hydraulic rams acting from both above and below. The pressure delivered at first is light, being only 240 pounds per square inch.[34] This is increased to 3700 pounds for completing the pressing.

[34] Missouri Geol. Survey, vol. xi, p. 502.

Since the green brick made by this method are rather soft they require some care in handling, especially to preserve the sharp edges. The bricks after being molded are usually carried directly to the kiln, since they contain comparatively little moisture. This last quantity is driven off in the kiln, but it must be done very slowly. The kilns used are mostly of down-draft pattern and the only essential difference of proceeding between the burning of dry-press and other bricks is that the former takes longer. It is claimed that for the burning of dry-press brick from one-sixth to one-quarter more fuel is required.

The advantages claimed for dry-pressed brick are cheaper cost of production, a product with very smooth faces and sharp edges, and simplicity of method. The initial cost of the machinery is considerable, however, and the sharp edges of the brick necessitate careful handling. Both plain and ornamental shapes can be made. The range of clays used is considerable, some of the types employed being quite sandy.

Dry-press machines are used to a very small extent in the State of Maryland. These machines require from 8 to 12 horse-power to operate them.

The number of dry-press machines on the market is small. Simpson Manufacturing Company, Winthrop, Illinois; Chisholm Boyd & White, Chicago, Illinois; American Clay-Working Machinery Company, Bucyrus, Ohio; Ross-Keller Brick Machine Company, St. Louis, Missouri.

Repressing.—Many front-brick are repressed after molding for the purpose of smoothing the sides and straightening the edges. Represses are operated by either steam or hand-power, the latter being used at yards where there is not constant employment for the apparatus. In a hand-power machine only one brick can be repressed at a time and one man and boy can commonly repress 2000 per day. The capacity of a 2-mold steam-power repress is about 25,000 per day of 10 hours. In each case the pressure is applied vertically and the dies have to be liberally oiled.

Repressing reduces the cubic volume of a brick somewhat.

FIG. 28.—Eagle repressing machine.

In Fig. 28 is shown one type of repressing machine, the Eagle Repress, made by the American Clay-Working Machinery Company, of Bucyrus, Ohio. Such a machine requires from 1 to 2 horse-power

to operate and represses from 1000 to 2800 brick per hour, according to conditions. Other makers are Ohio Ceramic Engineering Company, Cleveland, Ohio; Leader Manufacturing Company, Decatur, Indiana.

DRYING.

The water added to the clay to develop its plasticity has to be driven off before the clay can be burned.

The more plastic clays have to be dried with extreme care, since they have absorbed much water and in parting with it naturally shrink considerably. The rate at which different clays can be dried, however, varies greatly, some parting with their water very easily and others letting it go reluctantly. The latter naturally require a drying plant of much greater capacity for a given output. Fine-grained clays can seldom be dried rapidly unless the fine particles are sandy. The systems by which brick can be dried are the open yards, pallet racks, covered yards, tunnel driers and floors.

Open yards are simply well-drained floors of earth or brick on which the brick are laid after molding and are allowed to dry in the sunlight. They are only used at soft-mud yards and are open to the objections of limited capacity and damage to the bricks from rainstorms.

Covered yards are similar to the preceding, but are covered by a roof constructed in sections, which can be lifted in pleasant weather so that the sunlight can strike the bricks.

In both of these yards the bricks have to be turned from time to time during drying, after which they are "hacked" up in rows five or six courses high until they are taken to the kiln.

Pallet driers are covered racks for holding the boards, or "pallets," on which the bricks are dumped from the mold. They are much used at soft-mud yards, having the advantages of easy construction, cheapness, large capacity, and protection from rain (Plate XXV, Fig. 2).

All of the three methods above mentioned possess the disadvantages that they cannot be maintained in cold weather and are also hindered by damp weather in summer. To avoid this the use of artificial heat has been resorted to and employed in *dry tunnels*.

Tunnel driers.—With this method the green bricks are usually piled on cars and are run into heated tunnels to dry. The tunnels are about 100 feet long and constructed of either brick, iron or wood. If the bricks are of soft mud the pallets are set directly on the cars, but those of stiff-mud can be piled on each other, setting bricks of two successive courses at right angles to each other. Each car carries about 360 brick. The tracks are laid from the machines through the tunnels to the kilns. At each end of the system of tunnels there is a transverse track on which a truck can be run to bring the car of brick to the opening of whichever tunnel it is to be pushed into.

The tunnels are about 5 feet high and 4 feet wide and are heated by one of the following methods:

1. By a fire-place at one end and a system of parallel flues underneath.

2. By steam heat, the pipes being laid under the floor, or on the sides of the tunnel. Exhaust steam is used in the daytime and live steam at night (Plate XXVI, Fig. 2).

3. By hot air, the latter being drawn through the tunnel by natural draft or a fan. In some works the use of hot air drawn from the cooling kilns has been tried with much succes. It is often found necessary to have some means of mixing cold air with it, as that coming from the kilns may sometimes be too hot. These on the whole are a very good type.

Much depends on maintaining the proper flow of air through the driers, for if the current is too slow it may become surcharged with moisture and does more harm than good. Difficulty is often experienced in maintaining the same temperature at the top and bottom of the tunnel.

Six or more drying tunnels are usually set side by side and the drying may take from 24 to 40 hours, depending on the clay. The longer the clay takes to dry, the greater the number of tunnels which will be required for a given daily capacity.

Driers are made by the Chambers Brothers Company, Philadelphia, Pennsylvania, and the Standard Dry Kiln Company, Indianapolis, Indiana.

FIG. 1.—DRYING-FLOOR HEATED BY FLUES UNDERNEATH.

The Friedenwald Co.

FIG. 2.—TUNNEL-DRIER FOR DRYING BRICK.

Floor driers are used at some brick-works, although their application is more extended at fire-brick works. They are of brick, with flues passing underneath their entire length from the fire-place at one end to the chimney at the other. Such floors are cheap to construct but the distribution of the heat under them is rather unequal and a large amount of labor is required to handle the material dried on them (Plate XXVI, Fig. 1).

Slatted floors are at times used, but the practice is more prevalent in sewer-pipe manufacture.

A foreign custom, where continuous kilns are much used, is to set a series of drying-racks on top of the kiln. This is especially useful where the kiln is at a lower lever than the molding machine. While it necessitates extra handling, still it does away with the cost of the drying-tunnel. Drying-tunnels are made after essentially the same pattern, their chief difference being in the method employed to heat them.

BURNING.

Clay products after molding are burned for the purpose of converting them into that hard, rock-like form which makes them often more durable than many building stones. The changes which takes place during the process are practically the same in all clays but they vary in degree. These changes are both physical and chemical.

In burning, the last traces of moisture are driven off, and as the temperature of the clay reaches redness the chemically combined water and carbon dioxide also disappear, some of the latter being also furnished by the burning off of organic material which the clay may contain. The result is a loss of weight and also size, for the clay shrinks. Immediately after driving off the carbon dioxide the clay is very porous, but by further heating these pores close up, due to the softening of the clay particles. (See Fusibility.) The hardness of the material also increases with the degree of burning. The amount of heat applied in burning and the temperature reached depend on the nature of the clay used and the grade of product desired.

Common bricks are rarely burned to over 1800° Fahr., while pressed-brick are frequently fired at 2300° Fahr.

In the burning process a number of effects must be considered. Among these are the character of the clay, character of the fuel, type of kiln, temperature employed, and composition of the fire gases.

Clays when burned exhibit a variety of shades and colors. Many of these are dependent on the quantity and condition of ferric oxide and, to lesser extent, of other compounds associated with it, the fire gases and degree of fusion and temperature of the kiln. The red coloration produced by iron is well known, and other colors are mentioned under iron. An excess of lime, magnesia and alumina tends to exert a bleaching action of the iron, creating a buff tint. Five to six per cent of iron will produce a good red color.

Knowing the effect of the different ingredients on the color of the burned clay, it is possible, when certain results are desired, to add the necessary ingredients to the clay in case they are lacking. Thus a red-burning clay might be changed to a buff-burning one by adding to it a whitish-burning clay containing a high amount of alumina, and, depending on the amount added, we should get shades passing from red through brown, yellowish-brown to yellow. Marl produces a similar result.

The fire gases may be either reducing or oxidizing and, during the burning of a kiln, these conditions are likely to alternate at times, but while cooling down the action of the fire is, with few exceptions, oxidizing. The only way to get and keep it reducing is to burn very smoky fuel in the grates and then shut the kiln up tight.

One effect of the sintering is to cause the clay to shrink more and become denser, and this of itself is sufficient to deepen the color, but the color to which a clay naturally burns, as a result of its constituents, is best shown on the fractured surface of a brick, as the fire gases have not been able to exert any marked effect on the interior of the product. The surface coloration of a mass of burned clay may, therefore, often differ from the interior portion. This may be due to several causes. One of these is the accumulation of soluble salts which have been drawn from the interior to the surface of the ware by the evaporating moisture either during drying or water-smoking. This evaporation takes place most readily from the

FIG. 1.—ARRANGEMENT OF BRICK IN AN UPDRAFT SCOVE-KILN.

FIG. 2.—ARCH BRICK OF A SCOVE-KILN DISPLACED DURING BURNING.

upper surfaces, corners, or edges of the ware, and it is consequently on these spots that the accumulations, when they occur, are heaviest.

A second cause may be due to the deposition of foreign substances brought there by the fire gases, which may exert a colorizing action either by their presence alone or by their forming a glaze on the surface of the brick as a result of their union with the silica in it. This is often seen on the surface of the arch brick in an up-draft kiln, and on the surface of the bricks which line the back walls of a downdraft kiln.

A third cause is due to the difference in condition in the iron. If a clay containing the iron in a ferrous condition is heated too rapidly it may become dense before all the iron has been raised to a ferric condition. On breaking open such a brick it is found to have a bluish-black core and a red exterior.

If clay is properly burned, with access to air, it is probable that most of the iron remains in the ferric condition unless the ware is heated beyond vitrification, when a dissociation tends to take place and the iron goes over to a ferrous form.

Ferric oxide may produce all shades from pink to reddish black; manganese gives brown; an excess of lime, yellow and greenish yellow; ferrous oxide gives shades ranging from green to black. Furthermore, with any given quantity of clay the color will be deeper the higher the temperature. When the clay contains lime carbonate the latter serves as a flux and causes fusion to set in at a lower temperature than it otherwise would, the result being the formation of a complex silicate containing iron, alumina and lime. Up to the time fusion sets in the ferric oxide still imparts its red color to the clay, but as the heat rises this gradually turns to flesh red, white, yellow, and finally yellowish green. The coloration which is induced superficially is a matter of great importance, and, as before stated, may be due either to a coating of soluble salts or a deposit of impurities from the fire gases.

The discoloration produced by fire gases is far more pronounced in the case of buff ware. In red-burning clays the effect is often marked by a superficial reduction of the iron which the clay con-

tains or a slagging of the surface due to the deposition of fusible impurities, especially alkalis, from the fire gases.

In calcareous clays many of the elements of the material show a strong affinity for the sulphuric acid of the fire gas; the result of this is that sulphate of lime is formed on the surface, and the ferric oxide, not being able to unite with the lime, imparts a red color. In the interior the color of the brick remains yellow, for the sulphuric acid gas has not been able to penetrate to that point and take the lime away from the iron. This point can be easily proved by determining the amount of sulphur in the yellow and red portion of the brick.

One fact that this emphasizes is that in burning calcareous clays it is important that coal should be used which contains but a very small percentage of sulphur.

The slower the burning proceeds the more completely will the iron in all portions of the clay be oxidized, and the greater the access of air the brighter will be the red color.

Kilns.—The kilns used for burning bricks are of several different types, but all are built on one of two principles, known as the up-draft or the down-draft. In the former the fire is built in the bottom of the kiln and the heat passes upward through the bricks and out at the top. In the latter the heat is conducted to the upper part of the kiln, passes down through the wares and out through flues at the bottom.

The down-draft system is perhaps preferable, as the burning can be regulated much better and consequently there is less loss.

The simplest type of kiln with rising draft is what is known as a "scove" kiln, a form in use at many yards where common brick are manufactured. It consists in setting the bricks up in rectangular masses about 38 or 40 courses high. The bricks are piled up 6 over 2, that is, those of two successive courses are set at right angles to each other (Plate XXVII, Figs. 1 and 2). Those of the lower 15 courses (in Maryland) are set so as to form arches running through the mass about every two feet (Plate XXVII, Fig. I). After the bricks are set up the mass is "walled-up" with a double course of brick with a large amount of coal-dust in them, and the

whole daubed over with mud to make the mass as air-tight as possible, and also to prevent the heat from escaping.

At the present time many common-brick and practically all front-brick are burned in kilns which have four sides and a roof. The brick are thus thoroughly enclosed in a fire-tight and more or less air-tight chamber and the burning can be regulated much more easily than it could in the simpler types of kiln. Such kilns are both up-draft and down-draft. The fuel used in either up-draft or down-draft kilns varies, but at the present day coal probably finds

FIG. 29.—Vertical section of Grath coking furnace for burning clay products.

the greatest favor, although wood is employed at some localities and oil is found to be more economical at many others. At any rate, it is much commoner than either of the other two fuels, and is also the cheapest. When oil is used it is fed into the kiln through a burner which is located in each of the fire-places. If coal is employed as fuel it is sometimes placed on grate-bars or at other times the grate-bars are discarded and the coal is charged on the brick floor of the hearth. Still another type of furnace is that known as the Grath Coking furnace, which has a coking table about 16 inches above the combustion chamber. The fuel is first put onto the coking

table and part of the heat from the combustion chamber drawn under the coking table, thereby keeping the coal of the table red hot and driving the gases from it into the flues, where they are united and burned before being passed into the kiln. As soon as all the gases have been expelled the coke residue is pushed into the

FIG. 30.—Ground-plan of Grath coking furnace for burning clay products.

combustion chamber and there burned while a fresh supply of coal is added to the coking table.

Continuous kilns.—The one objection which has been urged very frequently to both the ordinary up-draft and down-draft kilns is the fact that they make no use of the waste heat, and in order to overcome this the Hoffman continuous kiln was devised. Since its invention by Hoffman numerous other types have appeared, many of

which are patented, but they are for the most part similar to the form proposed by Hoffman. The principle of the continuous kiln consists in having a series of chambers which are set either in the form of a circle, oval, or sometimes a straight line. Every chamber has a capacity of about 22,000 bricks and from it there are flues leading

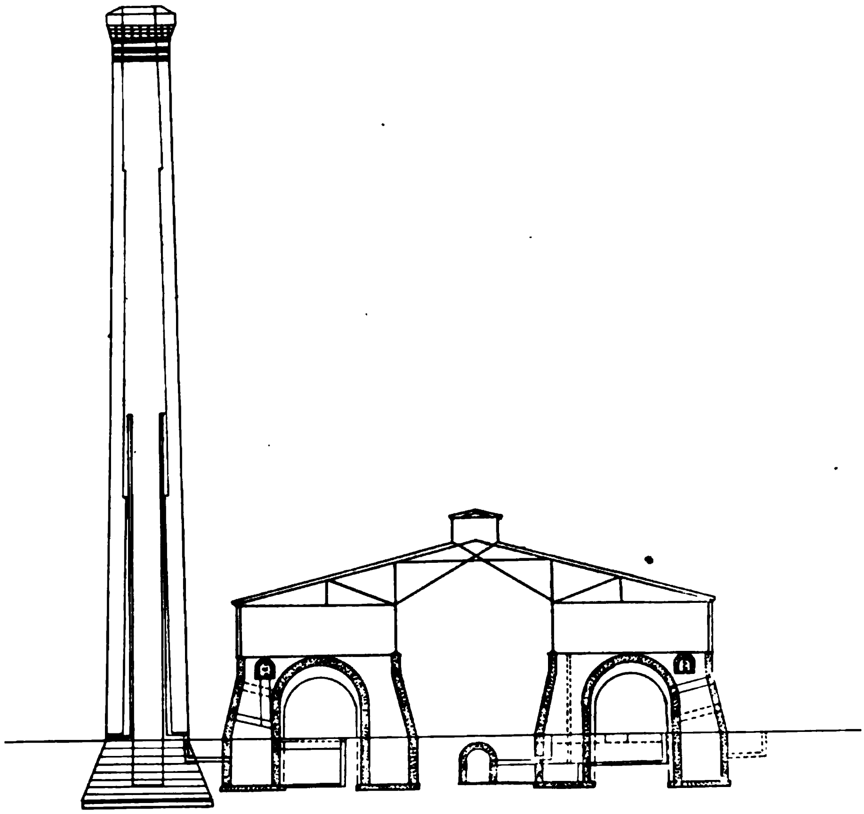


FIG. 31.—Section of Haigh continuous kiln.

to the central stack and also adjoining chambers on either side. There are also several holes in the roof of each chamber through which fuel can be introduced. The principle of the kiln is as follows: As soon as a number of the chambers have been filled with brick a fire is started in the first one. While the water-smoking vapors are passing off, the flues to the central stack are open, but as soon as the

water-smoking is done and the heated gases begin to escape, then the flue to the stack is shut and one is opened which leads to the next chamber of the series, so that this waste heat can be led not only through the following chamber but also through two or three chambers further on before it finally passes to the stack. In this way the waste heat of any one chamber is utilized to heat up the bricks of the several succeeding ones. As soon as the bricks in any one chamber become red hot, fuel, usually in the form of slack coal or sometimes crude petroleum is charged through the openings in the

FIG. 32.—Horizontal plan of Haigh continuous kiln.

roof, flues having been left in the setting of the brick in each chamber so that the fuel can pass down through them to the floor of the kiln. When any one chamber has reached its maximum temperature the next two or three chambers ahead of it are being heated up while those behind it are cooling down. It is thus possible to be burning brick in certain chambers, filling bricks into others and removing burned brick from still others all at the same time and thus the process may be kept on continuously. In some continuous kilns there is a solid brick wall between the different chambers, but in many of those used in the United States a temporary wall of heavy paper is put up during the setting of the brick. This wall lasts sufficiently long to prevent the free circulation of the air through

FIG. 1.—CIRCULAR DOWN-DRAFT KILN FOR BURNING PAVING-BRICK.

FIG. 2.—UPDRAFT KILN USED FOR BURNING COMMON BRICK.

the kiln and gradually becomes burned out. Owing to the cheapness and ease of manipulation continuous kilns are rapidly coming into use for burning brick, but up to the present time they have not been found thoroughly satisfactory for burning pressed-brick or fire-brick. The deficiency in the former case is due to the fact that it is difficult to obtain a uniform color in the burning throughout the kiln.

Plate XXIX, Figs. 1 and 2, show an interior view of an up-draft continuous kiln used at yard 17 of the Baltimore Brick Co., at Herring Run.

Paving-brick.

As is the case with almost every other type of clay product, a great variety of clays is used in the manufacture of materials for paving-brick. These include, therefore, common surface clays of residual or glacial origin, some refractory clays, and more or less easily fusible shales. While the first are used in some regions, still they do not always yield the best results, for they are sometimes too silicious or at other times too calcareous. Semi-refractory clays are utilized at a number of points, and in fact in former years it was considered that a refractory or semi-refractory clay was the only material from which brick could be made. The greatest number of paving-brick manufacturers at the present time seem to prefer fine-grained, moderately fusible shales. These shales have a wide geographical and geological distribution and it is indeed fortunate that such is the case. They are widely employed in a number of states, such as Ohio, Missouri, Illinois, Indiana and New York. One of the reasons why shales are found to be so well adapted for the manufacture of paving-brick is because, firstly, they are fine-grained; and secondly, they often contain the proper quantity of fusible impurities. These two characteristics permit the shale to fuse to a homogeneous mass at a comparatively low temperature. While paving-brick materials vary somewhat in their chemical composition, still the following will give the average of a number of shales used in the manufacture of paving-brick, 25 being from Missouri and 25 from other localities:[25]

[25] Missouri Geol. Survey, vol. ii.

COMPONENTS.	MINIMUM.	MAXIMUM.	AVERAGE.
Silica	49.00	75.00	56.00
Alumina	11.00	25.00	22.50
Ferric oxide	2.00	9.00	6.70
Lime	.20	3.50	1.20
Magnesia	.10	3.00	1.40
Alkalies	1.00	5.50	3.70
Ignition	3.00	13.00	7.00

These analyses show that the iron oxide, lime, magnesia and alkalies are usually quite high. In the following table there are given a number of separate analyses of paving-brick clays from different localities, and following that the physical properties of clay materials used for the manufacture of paving-brick at several important localities in the United States.

The following tests made on different clays and shales from different localities will illustrate fairly well the physical character of the raw materials used in the manufacture of paving-brick.

Carboniferous shale from the pit of the Saginaw Clay Manufacturing Company, one mile north of Flushing, Michigan.[26] The lower shale layer, or so-called fire-clay, requiring 20 per cent of water to work up into a moderately plastic mass with an air-shrinkage of 5 per cent. Tensile strength of air-dried briquettes from 60 to 65 pounds per square inch. Incipient fusion at cone 1, with total shrinkage of 10 per cent; at cone 5, shrinkage 11 per cent; vitrification at cone 7; viscosity at cone 11.

Upper shale from the same bank, hard and sandy in character. 20 per cent of water worked it up into a lean mass with an air-shrinkage of 3 per cent, total shrinkage up to cone 05, 5 per cent, with incipient fusion occurring at cone 1. At this latter point the color was red and the total shrinkage was 7 per cent. Vitrification at cone 6; total shrinkage, 9 per cent; viscosity at cone 8. Tensile strength from 35 to 40 pounds per square inch. A mixture of the two shales is used.

Carboniferous shale from Galesburg, Ill.[27] This requires 28 per

[26] Geol. Surv. of Michigan, vol. viii, part 1. Clays and Shales of Michigan, by H. Ries, p. 82.

[27] New York State Museum, Bulletin 35.

cent of water to work up. Air-shrinkage, 4 per cent; total shrinkage at cone 03, 10 per cent; vitrification at cone 2, and viscosity at cone 5. Tensile strength 60 to 70 lbs. per square inch.

Quaternary clay from Three Rivers, New York. 28 per cent of water required to work it up into a very plastic mass. Air-shrinkage, 5 per cent. Incipient fusion at cone 05, with a total shrinkage of 7 per cent; vitrification at cone 1 with 11 per cent total shrinkage. Viscosity at cone 3. Tensile strength of briquettes 60 to 70 lbs. per square inch. These figures are probably low.

Paving-brick shale, Coaldale, Alabama.[28] A yellowish-red shale with considerable grit. Mixes up to a lean mass with 22 per cent of water, and 4 per cent air-shrinkage. Total shrinkage up to vitrification, 9.5 per cent. Tensile strength, 25 to 35 lbs. per square inch. Incipient fusion, 1900° Fahr.; vitrification at 2000° Fahr., and viscosity at 2150° Fahr.

Clays which are to be used in the manufacture of paving-brick should possess fair plasticity since they are commonly molded by the stiff-mud process. They should also have a good tensile strength to resist tearing in the molding and drying and, furthermore, in order to permit the manufacture of vitrified brick with little loss and with sufficient economy their points of incipient fusion and viscosity should be at least 250° Fahr., or preferably 400° Fahr. apart. The shrinkage in drying and burning should also be low.

In manufacturing paving-brick it is the common custom to crush the shale in a dry-pan, although dintegrators are sometimes used where the material is not so hard. For grinding, the clay is screened with considerable care and then tempered either in a wet-pan or in a pug-mill.

Paving-brick are almost invariably molded on stiff-mud machines, the dies being made to produce either an end-cut or a side-cut brick. The green brick is furthermore often repressed in a second special machine shortly after being molded, the purpose of this being to densify the brick and reduce its laminated structure if possible, in case any exists, and to round off the edges. Clay technologists have

[28] Alabama Geol. Survey, Bulletin 6, p. 187.

not yet finally decided whether end- or side-cut brick are the stronger after repressing. Paving-brick are usually dried in tunnels in the same way that other brick are, and a variety of kilns are used for burning, although the rectangular down-draft type finds the greatest favor. In some regions round kilns are used to a large extent, but their capacity is usually smaller than those of the rectangular shape.

The important factor in the manufacture of paving-brick is to have a sufficiency of kilns to receive the brick from the machines so that the burning of the materials need not be hurried, for it usually takes from 7 to 9 days to burn the kiln, and while the temperature required for vitrification is rarely very great, yet at the same time it is extremely important that the brick should be cooled very slowly in order to prevent cracking. On the ordinary down-draft kiln it is commonly possible to produce from 80 to 85 per cent of pavers provided the burners know their business. While the continuous kiln has been used to a considerable extent in paving-brick manufacture, still its introduction has not been universal. One of the most successful is that of the Haigh type, shown in the accompanying illustrations (Figs. 31 and 32).

Enameled-brick.

Under this term are included those brick which have one edge covered with a coating of enamel, and are used to a large extent for interior work, on account of the decorative effect and clean appearance.

Enameled-brick are commonly made from a fire-clay, or mixture of clays, and they are molded either by the soft-mud, stiff-mud or dry-press process. In some regions they are made with an indentation on the upper and lower surfaces, while in Maryland there are two rectangular openings passing entirely through the brick. These spaces may serve to hold the mortar and thus permit a tight joint. A difficult feature in the manufacture of enameled-brick is to produce an enamel surface which shall be at the same time smooth and free from cracks. The cracks are due to the body and enamel having different coefficients of expansion.

The enamel is applied to the green bricks before being burned, or

in rarer instances the body is fired before applying the enamel. This latter necessitates a double firing, which increases the cost of manufacture. Enameled-brick are made of two different sizes, known as the English and the American size, the former being 9 x $4\frac{1}{2}$ x 3 inches, the latter $8\frac{3}{8}$ x $4\frac{1}{4}$ x $2\frac{3}{8}$ inches.

A wide range of colors has been produced in the enameling of bricks.

The burning is sometimes done in a muffle-kiln, at others in a down-draft one, the bricks being set with the enameled sides facing each other.

Terra Cotta.

The term terra cotta is used to define those clay products which serve a decorative as well as a structural purpose and are commonly of too great dimensions to permit their being molded in a machine. It is astonishing to see the way in which terra cotta has come to the front during the last few years and replaced stone to an alarming degree, so far as the quarrymen are concerned. This is not surprising, for in this material architects and builders have found a substitute for rock which is not only more durable, but also cheaper, lighter and susceptible of being produced in an almost endless variety of shades and colors. It can also be carved into more intricate and delicate designs than is often possible in stone. With the advances which have been made in the technology of the subject it has become necessary in most instances to use a mixture of many different clays in the manufacture of terra cotta goods in order to produce bodies of the proper physical qualities and also to get the proper shades and tints in burning. Indeed, the demand of architects has become such that in order to meet them the manufacturer has found himself obliged to resort to artificial coloring materials in the manufacture of his ware. On the whole it can be said that most of the clays used in the manufacture of terra cotta are somewhat refractory in their character, shales being used to rather limited extent and easily fusible clays being employed simply because they have some desirable burning color and on account of the high plasticity which they often possess. Since the clays which are used in the manufacture of terra

cotta are often used for the manufacture of other grades of clay products it is not possible to give a table of analyses of what might be strictly called terra cotta clays and therefore only four are given in order to show what a wide range of materials is used. These are (1) Devonian shale from Alfred Center, N. Y.; (2) Shale from Billings, Missouri; (3) Quaternary clay from Glens Falls, N. Y.; and (4) Cretaceous clay from Woodbridge, N. J.

COMPONENTS.	(1)	(2)	(3)	(4)
Silica	53.20	63.11	48.35	44.20
Alumina	23.25	23.11	11.38	38.66
Ferric oxide	10.99	1.79	4.02	.74
Lime	1.01	.42	15.38	....
Magnesia	.62	.70	3.17	....
Alkalies	2.69	3.71	6.05	.46
Water	6.39	7.05	....	13.55

The physical properties of terra cotta clay should be somewhat as follows: It should burn to a hard body at a moderately high temperature, say 2300° Fahr., producing a nearly impervious product. While it is desirable to have a vitrifiable clay, at the same time the burning of the body is seldom carried to this point for the reason that it is accompanied by too much risk from cracking by overshrinkage. Accordingly it is customary to use a semi-refractory clay which is burned to a good hard body, but not an impervious one. It is subsequently covered on the exposed surface by a coating of slip. This slip-covering serves two different purposes. In the first place it prevents the entrance of moisture into the ware, and secondly is used as a coloring agent, the various artificial or natural coloring compounds being put into it. In the manufacture of terra cotta the clay is usually first ground in a dry-pan, although sometimes it is previously exposed to the weather. The weathering is done partly for the object of disintegrating the clay, thereby increasing its plasticity, and partly for the purpose of allowing nodules of iron to weather out and make their presence known so that they can be readily seen and removed. The ground clays are sometimes tempered in a wet-pan, and after this may be subjected to still further mixing in a pug-mill attached to the Auger stiff-mud machine. The latter has a very large die, so that when the clay issues from it, it is

FIG. 1.—UPDRAFT CONTINUOUS KILN, SHOWING DAMPERS.

The Friedenwald Co.

FIG. 2.—INTERIOR VIEW OF UPDRAFT CONTINUOUS KILN.

cut into cubical lumps of about 8 x 8 inches on an edge. These lumps are then piled away in bins until ready for use, when they may go through additional pugging to soften them for molding.

Terra cotta objects are always molded by hand, it being necessary, however, in the first place to make a clay model of any object to be molded so that around this a plaster mold can be formed. If the object is simple in design and small in size it can be made in one piece, but intricate designs almost invariably have to be molded in two or three or even more parts. In filling the plaster mold the tempered clay is well pushed into all corners and crevices, covering the entire interior of the mold to a depth of about two inches. After this the mold is set aside to dry for several hours in order to permit the clay to shrink sufficiently to permit its removal from the plaster form. Any rough or uneven edges are then usually trimmed off with a knife. If only one object of a given design is to be made it is sometimes customary to model the object directly in clay and then burn it, but such work requires the services of a skilled modeller and these pieces have to be dried with exceeding care. Terra cotta is usually dried on floors heated by steam, and in the case of large objects has to be done so slowly and carefully that it may occupy a number of days. Large objects, such as column or shaft, are stood first on one end and then on the other. Objects are often turned from one side to the other to facilitate equal shrinkage and drying in all directions. After it is thoroughly air-dried the green ware is taken to the spraying-room, where the slip which is to form the surface coating is spread on it, thus forming a thin layer all over the surface and even being absorbed to some extent. This slip is a mixture of kaolin, quartz and feldspar, and coloring ingredients mixed in proper proportions to have the same fire-shrinkage as the body and thus avoiding its cracking in the kiln. Terra cotta objects are commonly burned in down-draft, circular kilns, less often in the rectangular ones. The former are commonly from 15 to 25 feet in diameter. Some manufacturers use a muffle-kiln, which is similar in its construction to the circular kiln, but differs from it in that it has a double wall through which the fire passes upwards and then comes

downwards through a central stack. This prevents the flames from coming in contact with the ware and discoloring it in any way.

The total shrinkage of terra cotta in drying and burning is commonly about 1/12. More care has to be taken in placing the ware in the kiln than is necessary in the case of any other grades of structural products, for, owing to the complicated shapes which are often made, it is extremely important that green ware should not have to bear any weight during the process of burning. This is done by surrounding the pieces by a framework of slabs made of fire-clay and grog. As the clays used in the manufacture of terra cotta vary considerably in their pyrometric characters there is consequently considerable difference in the temperature reached in the kilns at different factories. With calcareous clays the temperature probably does not exceed cone 05 or 03, but with semi-refractory clays a temperature equal to the fusing-point of cone 7 or 8 is no doubt often attained. The pieces of large designs are all carefully fitted together before being shipped from the factory.

Any warped edges that may occur have to be straightened out by grinding or chiselling, but at the present time the manufacturer who is thoroughly familiar with the shrinkage and behavior of his clay is usually able to produce objects of exactly the required dimensions. Still accidents may often happen in the best regulated works, and where an extremely intricate design is called for it is often customary to mold duplicate pieces so that in case one has a mishap in burning the other may be saved.

There would be little value in giving analyses of materials used in the manufacture of terra cotta, for the reason that they are seldom used singly, but in mixtures.

Roofing-tile.

The clays used in the manufacture of roofing-tile may also show considerable variation, but probably not as great as in the case of terra cotta. The essential qualities of clay or shale for this purpose are that it shall have good plasticity, good tensile strength, and dry and burn without excessive shrinkage or warping. It should also burn to a dense body. Roofing-tile are made in several different

shapes, the most important ones being as follows: Shingle-tile, which are perfectly flat and of the same shape as a wooden shingle. Pan-tiles, which are curved and laid with the arched side longitudinally up and down so that one overlaps the other. Interlocking tiles, which are perhaps, in many respects, the best type made. These are provided with a series of longitudinal and transverse depressions on one-half and ridges on the opposite side of the other half, so that the ridges of one fit into the depressions of the next one below. Roofing-tile are made either vitrified or porous and covered with the glaze, and both types are much used. The former is perhaps the most desirable, since it insures a thorough resistance to the weather. The latter is, indeed, lighter. Interlocking tiles usually give the tightest form of roof and do not have to be laid in cement, but in order to fit tightly there must be absolutely no warping of the ware in the burning. They are best adapted to a steep rather than a flat roof. Shingle-tile are adapted to any slope of surface and make a fairly tight roof. The pan-tiles have to be laid in cement and are usually porous. Both the shingle- and the pan-tiles may be salt glazed or covered with a fusible lead glaze. This latter type of glaze is the one used on the roofing-tile made at Baltimore which can be seen on a number of the large buildings in the city, such as the Woman's College and the State Prison. While glazes, especially if colored, add greatly to the ornamental effect of the tile, at the same time they should only be used for this purpose, it being very undesirable to protect the body of the ware against the weather. In order to prevent warping and excessive shrinkage in the burning of roofing-tiles much care is taken in the selection and proportion of the raw materials. Shales are commonly ground so as to pass through a rather fine screen such as 20 meshes to an inch and the tempering is done either in a wet-pan or pug-mill, but preferably the latter. Shingle-tiles can be molded in an Auger stiff-mud machine whose die has such a shape that the clay issues from it in the form of a ribbon, having proper width and thickness which can be cut into proper lengths. Pan-tiles may be molded by the same process. Interlocking tiles require a special form of treatment, since the presence

FIG. 33.—Press for making roofing-tile.

of the transverse ridges on the surface does not permit their being molded in an Auger machine die. The common method, therefore, is to run the clay through an Auger machine, cutting it up into slabs, each of which contains sufficient cubic inches to make a tile. These slabs are then put into the tile press and repressed, coming from the machine in the form of the interlocking tile. Whatever the form of the tile or the method by which it is molded, it is common to receive it on a wooden or plaster pallet as it comes from the machine, since on account of its thinness it is not always stiff enough to hold its shape. The special form of tile press used in the manufacture of interlocking tile consists of a hexagonal prism (Fig. 33) which forms the under half of the mold. This is set into a steel frame and revolved by special gear wheels. The upper half of the mold is formed by a plunger set in the upper part of the machine. The prism revolves just enough each time to move one of the faces into a horizontal position on top and directly below the plunger and as soon as it reaches this position one of the slabs of clay is laid on it, the plunger descending and pressing the soft material out between the two faces of the mold into the desired form. The plunger is then raised and the prism turns another 60 degrees to receive another slab. As soon as a face with one of the pressed slabs reaches the lowest point of the revolution the molded tile drops off and is received onto the pallet.

This form of machine was originally made in Europe, but has been copied in the United States with considerable success. There are two types of molds made; one is a plaster one and the other of steel, which has to be kept heated or oiled to prevent the clay from sticking. The disadvantage of the plaster molds is that they wear out rapidly, and furthermore are not sufficiently strong to permit the clay to be pressed very stiff. The capacity of a roofing-tile repressing machine ranges from two to five thousand tile per day.

The tile on the pallets are stacked up on the shelves of the drying-room or else placed on cars and run through drying-tunnels. For burning, the type of kiln varies and depends largely on the individual taste of the manufacturer; the tile are usually set up on end and

surrounded by slabs of fire-clay to protect them against the weight of those above. Most of the tile manufactured in this country are red, but buff, brown and other colors are seen at times.

Floor-tile.

These are made from a variety of clays, and in addition often have a considerable percentage of other materials added in for the purpose of fluxing. Two general types of floor-tile may be recognized, namely, encaustic tile and tiles of solid color. In the former the pattern of the tile is formed by the thin layer of different colored clays on the upper surfaces of the tile. In the latter the tile is of one color, which extends through the entire body. Floor-tile are, with few exceptions, made by a dry-press process, which is indeed especially necessary in the manufacture of encaustic. It is next to impossible to make any statement regarding the qualities of the clays which are or should be used for the manufacture of floor-tile, for the reason that such a wide variety of materials is employed. Semi-refractory ones are very frequently used for the body, plastic ones may be used if abundant, perhaps, and ferruginous ones may, in some cases, be just what is wanted to produce the red color. The main points are that a mixture is desired which will burn to a hard, dense body, and have in burning a moderate percentage of shrinkage and a comparatively low fusing-point. Floor-tiles are subjected to severe usage, for they must not only stand weathering when used out-doors, but they must also resist abrasion and hard knocks. In making white and buff tiles, manufacturers often use a large percentage of feldspar. In spite of their hardness and apparent density the tiles may often show considerable porosity, it being found from tests made on different colors that the percentage of absorption by white averages from 4.5 to nearly 8.5 per cent, being apparently greatest in even-colored ones, and least in dark gray, although this may simply have been the case in the series which were examined.

Sewer-pipe.

For the manufacture of this grade of clay products the material required is somewhat similar to that used in the stoneware bodies.

This means that the clays should be sufficiently plastic to permit molding without cracking. They should have a good tensile strength,

FIG. 34.—Pipe press used in pressing sewer-pipe.

of from 125 to 150 lbs. per square inch, and they should burn to a hard, impervious body at a moderate temperature. Owing to their

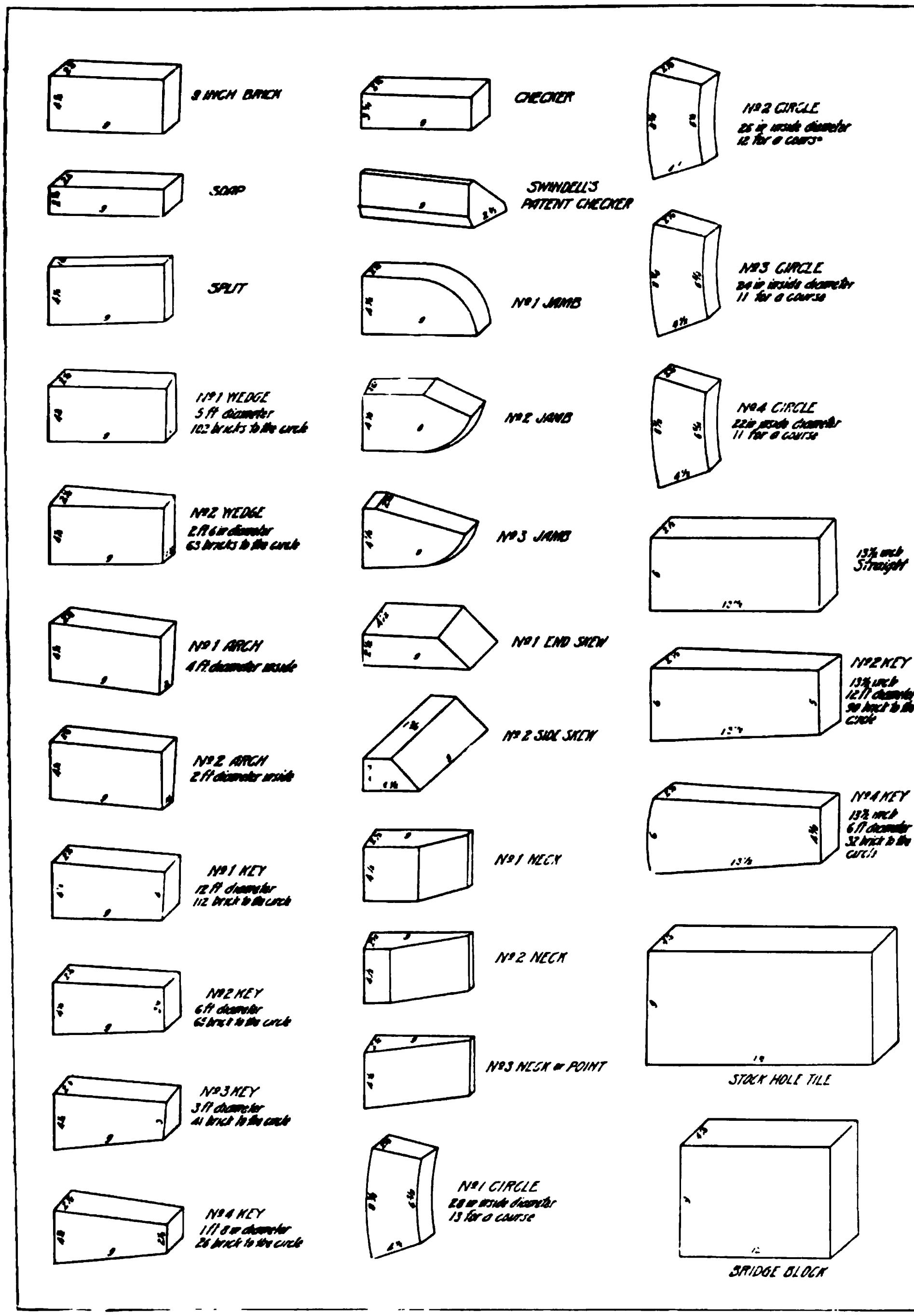
peculiar shape, it is also necessary that in the burning they should hold their form without bending. On this account it is frequently found that the manufacturer employs two clays, one, to serve as a binding material, the other to help the ware to hold its shape during the firing. The glaze seen on the surface of sewer-pipes is what is known as a salt glaze and is given to the ware by adding salt to the fires during the period of maximum temperature. Some manufacturers glaze their pipes with slip clay instead of salt, but this is an expensive proceeding which has absolutely no advantage. At some localities shales and other semi-refractory clays are used in sewer-pipe manufacture, or again surface clays may be found to give the best results in the region where they are employed. In Maryland a mixture of Arundel clays is used. The tempering of the sewer-pipe is often done by the usual methods, but the molding has to be carried out in a special form of machine known as the pipe press (Fig. 34). This consists of two cylinders, an upper one called the steam cylinder and a lower one known as the clay cylinder. The lower one is filled with clay, which is forced down by a piston connected by a second one in the overlying steam cylinder, the two being on a common piston-rod. The clay issues from the die at the lower end of the clay cylinder. When the sewer-pipe has issued to a sufficient distance the pipe is cut off and the section received on a pallet as it leaves the machine. Small diameter pipe can be dried very rapidly, but larger ones must be treated with extreme care, the drying process sometimes requiring several weeks. Circular, down-draft kilns are commonly used in burning sewer-pipe, and this process, on account of the thinness of the ware, can be carried on with considerable rapidity.

Hollow brick, used in the construction of fire-proof buildings, are sometimes molded on a sewer-pipe press.

Refractory Goods.

FIRE-CLAYS.

Under this caption are included those clays which are able to withstand a high temperature. It, therefore, in the present treatment, takes in those materials whose fusion-point is equal to, or



The Friedenwald Co.

FORMS OF FIRE-BRICK MADE IN MARYLAND.

higher than that of cone 27. The term fire-clay does not indicate anything regarding the character of the material beyond its heat-resisting qualities. They may, therefore, vary widely in their plasticity, shrinkage, texture, color, tensile strength and other physical properties. They do, however, agree more or less closely in their chemical properties in having a comparatively low percentage of fluxes. It is unfortunate that many clays are denominated fire-clays which are not really such. Two types of fire-clays are recognizable, namely, plastic and non-plastic or flint clays, and both of these are found in Maryland. The flint clay often stands very close in composition to kaolinite and may be almost identical in its composition to certain plastic clays, and yet for some reason not hitherto well explained it develops little or no plasticity in grinding, no matter how finely this is done. Flint clays may occur in the same bed with the plastic fire-clays, but they do not necessarily keep any fixed position, sometimes the one being on the top, sometimes the other. Or in some cases the two are mixed in together. Flint clays are hard and usually have a conchoidal or shell-like fracture, and may also have a marked lustre. In some deposits of flint clay the iron seems to have segregated into concretionary masses, thus freeing the surrounding clays from ferruginous impurities, and these concretions or iron-balls can often be picked out easily during the process of mining. Plastic fire-clays are sometimes soft and plastic in nature, at other times they occur in the form of apparently hard shales which, however, may develop moderate plasticity on grinding and mixing with water, or this may be greatly increased by allowing them to lie exposed to the weather for several years. The color of the fire-clay is not always an indication of its refractoriness. If the clay is highly colored by iron the chances are that it is not very fire-resisting, and yet a very sandy clay may be highly colored by a comparatively small amount of iron. Whatever the color of the fire-clay in its unburned condition, it is always buff when burned. The refractoriness of a fire-clay will depend primarily on its chemical composition, but aside from this the coarseness of grain may also have much to do with it, as explained under the chapter on fusibility of clays.

ANALYSES OF FIRE CLAYS.

State and County.	Town.	Remarks.	Silica.		Alumina.	Ferric Oxide	Lime.	Magnesia.					
			Combined.	Free.									
Alabama:													
Calhoun	Jacksonville..	White clay...	44.6		38.92	.78	....	1.08					
Choctaw	......	Hard clay.....	36.3		5.12	1.6	.46	....					
Arkansas:													
Lawrence.	Black Rock...	......	84.24		11.5	.08	.52	.02					
California:													
Amador.......	Carbondale. ..	Washed clay..	59.96		30.29	.27	.28	....					
Colorado:													
Jefferson......	Edgemont ...	......	46.61		37.2	.15	.44	.25	1.33	13.65	.47	.....	M. Moss, Anal.
Pueblo	Pueblo.......	Clay	28.76	34.46	24.72	.43	.3	.13	tr.	8.63	1.36	TiO₂ .38 Org. .4 Loss 10.80	Steiger, Anal.
Delaware:													
Newcastle.....	Wilmington ..	......	72.4		14.8	tr.	.85	....	.85	.5		Loss 12.4	Ind. Geol. Sur 1878, p. 158.
Georgia:													
Floyd...	Flowing Branch	......	41.2		38.6	1.45	....	.3	.11	16.7		TiO_2 1.95	Ga. Geol. Sur., 1893, p. 280.
Illinois:													
Mercer	New Windsor.	......	76.1		15.04	a1.08	.62	.3	1.55	5.3		. . .	Crossley, Analyses of Clays.
Indiana:													
Lawrence	Huron	Indianaite....	40.5		36.35	.15	....	.13	.14	22.6		....	
Parke.........	Bloomingdale	......	69.83		14.27	2.13	.9	.6	12.28	....		....	Helwig & Hobbs. Anal.
Iowa:													
Dallas	Van Meter...	......	86.63		10.92	.1	....	....	...	2.32		....	W. S. Robinson, Anal.
Kentucky:													
Ballard	Blandville....	......	74.84		16.58	1.4	.269	.209	1.576	5.126		....	Ky. Geol. Sur., Chem. Rept. A, Pt. 8. p. 14.
Carter........	Boone Furn'ce	......	48.56		37.471	tr.	.112	tr.	.572	13.03		P_2O_5 .255	Ky. Geol. Sur., Chem. Rept. A, Pt. 1, p. 44.
Carter.... ...	Grahm's Sta'n	Plastic clay...	45.4		40.04	....	tr.	tr.	.21	14.85		...	Louisv'e Fire Brick Works.
Hickman	Columbus. ...	......	85.18		10.26	1.12	tr.	.064	1.1	2.276		....	Ky. Geol. Sur., Ch. Rept. 4, Pt. 3, p. 60.

ANALYSES OF FIRE CLAYS—Continued.

State and County.	Town.	Remarks.	Silica. Combined	Silica. Free.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water. Combined.	Water. Free.	Miscellaneous.	Firm Names, Authority or Analyst.
MARYLAND:													
Allegany......	Mt. Savage...	Flint clay.....	50.47		35.904	1.504	.133	.018	....	12.74		...	Anal'd at Mass. Inst. Tech.
MISSOURI:													
Callaway	Fulton.	Used for fire brick	47.3		37.54	1.48	.57	....	.5	12.76	....	....	Mo. Geol. Sur., xi: 563.
Franklin.	Dry Branch...	Flint clay for fire brick....	42.6		41.88	.62	.28	.2	.54	14.	....	....	Mo. Geol. Sur., xi: 564.
St. Louis......	Cheltenham...	... ..	38.1	12.7	31.53	1.92	....	tr.	.4	11.3	2.5	TiO_2 1.50	Evans & Howard.
St. Louis......	St. Louis, Christy Cl. Co	Washed fire clay........	64.35		21.16	2.63	.61	.3	.51	8.94	2.63	1.07 SO_3 .35	Mo. Geol. Sur., xi 568.
St. Louis......	St. Louis, Christy Cl. Co	Used for fire brick.	61.73		23.56	5.16	.55	.15	1.	9.25	2.94	SO_3 .56 TiO_2 .96	Ibid.
St. Louis......	St. Louis, Jamieson Fr'ch Fire Clay Co.	Washed pot clay........	52.52		31.4	2.34	.4	.42	.61	....		b 12.42	From the Co.
St. Louis... ..	St. Louis, Parker & Russell	Fire brick and gas retorts..	67.47		19.33	2.56	.41	.07	1.07	7.73	2.72	SO_3 .24	Mo. Geol. Sur., x 570.
NEW JERSEY:													
Middlesex.....	Burnt Creek..	Washed clay..	42.9	1.5	38.34	.86	....	...	.44	13.5	1.1	TiO_2 1.2	N. J. Clay Rept., 1878, p. 197.
Middlesex.....	So. Amboy....	Paper clay....	42.71	.7	39.24	.46	.2	....	.89	13.32	1.58	TiO_2 1.6	Ibid., p. 200.
Middlesex.....	Woodbridge ..	......	61.6		28.38	.52	.46	.36	....	....		TiO_2 3.6 Ign. 5.08	J. Pohle, Anal., W. R. Dixon, Est.
Middlesex.....	Valentine & Co., Woodbridge......	......	56.82		32.4	.15	....	....	10.04	....			Furnished by H. Burden, 2nd.
NEW YORK:													
Richmond.....	Kreischerville	......	64.28		24.76	.88	.73	tr.	2.35	....		....	H. T. Vulté, Anal.
NO. CAROLINA:													
Cleveland.	Grover.	.....	68.28		18.83	2.6	.7	.13	2.29	6.47	.76	TiO_2 .27	Eskridge's Pit, Bul. 13, N. C. Geol. Sur., p. 81.
Guilford......	Pomona......	......	70.45		17.34	3.16	.25	.22	.7	6.63	.98	Ferr. Ox. .33	First Pit, Pomona Terra Cotta Co. Ibid., p. 84.

ANALYSES OF FIRE CLAYS—Continued.

State and County.	Town.	Remarks.	Silica. Combined.	Silica. Free.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water. Combined.	Water. Free.	Miscellaneous.	Firm Names, Authority or Analyst.
NORTH DAKOTA:													
Stark..........	Dickinson....	......	72.66		17.33	1.05	.13	....	.74	9.35		....	
OHIO:													
Columbiana. ..	Salineville ...	Flint clay....	59.92	....	27.56	1.03	tr.	tr.	.67	9.70	1.12	....	Ohio Geol. Sur. vii, 1893. p. 220.
Summit.	Akron	......	51.21	8.132	27.62	tr.	....	.029	2.07	....		....	
Tuscarawas ...	Mineral Point	Flint clay....	35.39	17.13	31.84	.67	.5	.19	.59	11.68	.69	TiO_2 1.68	Ohio Geol. Sur. vii, 1893. p. 220.
PENNSYLVANIA:													
Armstrong. ...	Kittanning ...	......		97.03		.9	....	.11	....	.15		....	
Clearfield	Clearfield (5-miles S. W.).	......	44.05		37.51	a.819	.49	.181	.065	15.21		TiO_2 1.84	Queen's Run Fire Brick Co.
Indiana.	Black Lick...	Flint clay ...	64.83		23.95	a.9	.11	.187	.296	9.39		TiO_2 .88	Pa. Geol. Sur., H 4, p. 194.
			68.49		18.46	a1.566 .29	.23	.551	2.755	6.31		TiO_2 2.15	
Indiana.	Bolivar.......	......	59.83		24.58	a1.655	.28	.872	3.114	7.83		TiO_2 1.17	Pa. Geol. Sur., MM. p. 259.
Somerset......	Savage M't'n..	Raw flint clay	53.86		35.484	a1.23	.302	.144	....	8.75		....	Welch, Gloninger & Maxwell. Anal.
Somerset......	Savage M't'n..	Calcined flint clay.	59.16		38.7	a1.36	.331	1.36	....	....		....	
Westmoreland.	King Mine....	Flint clay....	63.81		26.39	1.23	tr.	tr.	....	Ign. 9.12		....	1897 Rep't Pa. State Coll.
SOUTH DAKOTA:													
Pennington ...	Rapid City....	Hard clay.....	84.42		9.41	1.07	tr.	.39	....	3.42		....	Rapid City Steam Brick Works.
TEXAS:													
Montague.....	Bowie........	......	60.48		24.6	2.43	.89	.75	....	....		....	Montague Coal Mining Co.
WASHINGTON:													
King	Bl'k Diamond Field	......	57.5		34.37	1.24	.5	1.0	.68	4.71		....	1891 Rep't Wyom. State Geol.
WEST VIRGINIA:													
Fayette.	Gr't Kanawha	......	55.67		30.39	.61	.37	tr.	.12	12.87		....	W. A. Bradford. Anal.
WYOMING:													
Albany	Rock Creek...	......	59.78		15.1	2.4	.73	4.14	....	16.26		....	Bull. 14, Wyoming Exper. Sta.

In Plate LXVIII are shown a number of specimens of Maryland fire-clay which have been heated up to the fusing-point of cone 27 in the Deville furnace. Those which retain erect form were only slightly or not at all affected by the temperature reached, while those which were semi-refractory in their character melted down to a rounded mass. It is rather difficult to study the permissible limit of fluxes in fire-clay, but it can be said in general that they should not exceed 4 per cent. In the following tables there are given a number of analyses of fire-clays.

MANUFACTURE OF REFRACTORY CLAY BRICKS.

Fire-bricks represent the commonest type of fire-clay products and probably most of the fire-clay mined is employed for this purpose. Fire-clays are utilized in many different ways and consequently not only the shape but quality varies. In Plate XXX are illustrated a number of shapes of fire-brick made in Maryland. In some cases a fire-clay may have to stand temperature alone, while in other cases it must resist the molten slag or metal, or in still other instances it has to resist abrasion. Where resistance to corrosion is essential it is desirable to use a clay which burns to a very dense body at a comparatively low temperature. This property is best shown in glass-pot clays. Where fire-bricks are used for lining coke ovens, they must not only be quite porous, but they must also withstand sudden changes, for at the end of the coking process it is customary to turn a stream of water into the red-hot oven. Some manufacturers have found that a porous brick of very high silica content does excellently in this kind of work. Among the many other shapes of refractory goods made may be mentioned locomotive and steamboat tile, steel runners, sleeves, nozzles, crucibles, stove-linings, glass-pots, gas-retorts, tuyères, rolling-mill tiles, hexagonal stove shapes, grate-backs.

Fire-bricks are usually made of a mixture of clays to which there is added a certain quantity of ground fire-brick or burned clay, and sometimes sand. In Western Maryland a mixture of plastic and flint fire-clay is used with a certain percentage of grog or ground fire-brick. Around Baltimore, fire-brick are made of a mixture of

coarse sandy kaolin, of residual nature, and plastic Arundel clay. If the clay is in the form of a shale it is commonly ground in the drying-pan, and the old bricks which serve as grog are treated in the same machine (Plate XXXI, Fig. 2). The several ingredients of the fire-brick mixture are often put into a large pit, one layer over another, and the total mass thoroughly soaked with water, after which it is sometimes additionally mixed in a pug-mill, and then sent to the molding tables. The old method of molding fire-brick was by hand, and while for a time many manufacturers tried to use machines for molding, still most of them have gone back to the old hand method. It is claimed by many that molding machines make the brick too dense and impair its fire-resisting qualities. After the fire-brick are molded they are commonly set on hot floors to dry (Plate XXVI, Fig. 1) for a few hours before they are repressed. The burning of fire-brick is done either in up- or down-draft kilns, which may be circular or rectangular in form. At Mt. Savage two continuous kilns are used, the fuel being generated by a gas producer as described in another part of the report. While many refractory clays have been found in the State, still none of those yet discovered are considered suitable for the manufacture of glass-pots. A clay to be used for this purpose must not only be of very high refractory quality, but it must also possess high plasticity for high temperatures and burn dense at a very low temperature, namely, about the fusing-point of cone 3 or 4.

Pottery Manufacture.

Pottery includes articles of a domestic or ornamental nature which can be turned on a potter's wheel. With the improvement of processes known and the invention of new wants, the potter's wheel has been in some cases replaced by other types of machines which do the work of molding more rapidly and also more perfectly. Before referring to the methods of manufacture of pottery it may perhaps be well to refer to the different types which are recognized.

Earthenware.—This includes the lowest grades of pottery, such as common flower-pots, which are usually made from medium or poorer grades of clay. Very calcareous clays are sometimes used, in fact they are desirable on account of the porous body which they form in

FIG. 1.—UPDRAFT KILN FOR BURNING FIRE-BRICK.

The Friedenwald Co.

FIG. 2.—PAN FOR GRINDING GROG AND FIRE-CLAY.

burning. The body is commonly red or buff in color and quite porous. On this account it is also very permeable to water and can only be made tight by covering with a glaze. In recent years much ornamental earthenware has been produced with the glazed or slipped surface.

Stoneware.—This differs from earthenware partly in the nature of the clays used and partly in the character of the body, which is always vitrified, and in order to attain these results it is of course necessary to select materials which are somewhat better in their quality than those employed in the manufacture of common earthenware. The color is commonly red, buff or bluish-black, but owing to the coating which is put on the surface, the true color of the body does not always show. In the manufacture of stoneware the burning and the glazing are usually done in one operation, and if the ware is coated with slip the latter is applied to the unburned clay. The uses of stoneware are chiefly domestic, although much ornamental pottery has a stoneware body. In the last few years the stoneware industry of the United States has been wonderfully expanded. This is partly due to the manufacture of cooking utensils made of clay, the nature of the body being such that the ware can be set directly over the fire and food cooked in it.

Stoneware is usually made from a refractory or semi-refractory clay and the best results are naturally often obtained by employing a mixture of several different materials. The clays used should in all instances have sufficient plasticity to permit their being molded without cracking, and their tensile strength should not be less than 125 lbs., while 150 is, perhaps, preferable. The clay should also show a low fire-shrinkage and if possible burn to a vitrified body at at a temperature not over 2100° Fahr. At the same time the raw material should contain enough refractoriness to hold its form well at a temperature required to melt the glaze and not do more than to soften at that heat. In the table of analyses given a few pages further on will be found the composition of stoneware clays from different localities, and following that are several examples showing the physical character of well-known stonewares.

Yellow and Rockingham ware.—These differ from stoneware in that the body is burned first, and then glazed and burned again. It is

similar to stoneware in that it is made with a natural clay, but agrees with white earthenware or porcelain in being put through two fires. In yellow-ware the body is covered with a transparent glaze of low fusibility, while in Rockingham ware the glaze has a black or brown color due to the addition of manganese.

C. C. ware and white granite-ware.—These are made of high-grade clays which mix with other materials. The mixture commonly consists of kaolin to form the body, ball-clay to supply plasticity or binding power, silica to prevent excessive shrinkage, and feldspar to serve as a flux. The raw materials used in the manufacture of C. C. ware are not quite as high as those employed for the manufacture of china or porcelain. In white granite-ware or iron-stone china the best grade of materials are used, but the body is only burned to incipient fusion and is therefore not impermeable, differing in this respect from porcelain. Indeed, it may be said that white granite bears the same relation to porcelain, that earthenware does to stoneware. The materials used in the manufacture of both white granite and porcelain have to be selected with extreme care, for anything but a small quantity of iron will prove very injurious.

Porcelain.—While the same materials are used in this body as in that of white granite, still their proportions are usually different, being such as to permit the ware being burned to vitrification, thereby producing a transparent, vitreous ware. The flux which is commonly used to aid in the vitrification is feldspar, but in some localities lime is at times employed. The great aim of the porcelain manufacturer is to produce a ware which will burn and vitrify at a low temperature and do so with but little shrinkage. The glaze used on a white granite and C. C. ware is a mixture of kaolin and fluxes, lead being among the most important of the latter. On the porcelain the glaze consists chiefly of feldspar and kaolin and contains no lead. This is spoken of as a hard glaze, while that of the white granite is known as a soft glaze.

In the following table are given the analyses of a number of pottery clays and also kaolins. Following this there are also given a number of physical tests which have been made on pottery clays from different localities:

The Friedenwald Co.

VIEWS ILLUSTRATING THE PROCESS OF TURNING JARS.

ANALYSES OF POTTERY CLAY.

Water.

ANALYSES OF POTTERY CLAY.

State and County.	Town.	Remarks.	Silica. Combined.	Silica. Free.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water. Combined.	Water. Free.	Miscellaneous.	Firm Names, Authority or Analyst.
ALABAMA:													
Fayette......	W. Doty......	Stonew'e clays	65.58		19.23	4.48	tr.	tr.	....	5.5	1.4	....	Bull. 6, Ala. Geol. Surv. p. 175.
Fayette......	13 mi. from Fayette C.H.	Stonew'e clays	67.1		19.37	2.88	tr.	.725	.672	6.08	1.71	....	Ibid. p. 176.
GEORGIA:													
Baldwin......	Stephens Pot'y	......	46.07		21.72	15.75	.25	.67	.48	11.72		c .34	R. Peter, Anal.
KENTUCKY:													
Madison......	Waco........	Pottery clay.	59.976		27.64		b.28	.606	4.478	7.02		....	Ky. Geol. Sur. Chem. Rep't A, Pt. 1, p. 109.
MISSOURI:													
Barton.......	Wear Mine, Minden	Not worked...	50.94		24.24	7.18	.95	1.6	3.6	11.58	....	....	Mo. Geol. Sur. xi: 563.
Callaway.....	Moore Place, near Guthrie	Used for stoneware........	48.92		32.9	3.1	.4	.37	.82	13.58	....	....	Ibid.
Henry........	Calhoun	Used for stoneware.......	71.94		17.6	2.35	.62	.56	1.5	5.27	1.01	....	Ibid. xi: 564.
Jefferson.....	Mandel's Pit, Regina.....	Ball clay for white ware.	45.97		36.35	1.08	1.14	1.09	1.84	12.36	....	....	Ibid. xi: 566.
NEW JERSEY:													
Sussex.......	Woodbridge..	Stonew'e clay.	19.44	48.4	21.83	1.57	.28	.24	2.24	5.9	.8	....	N. J. Clay Rep't, 1878, p. 99.
NEW YORK:													
Suffolk.......	Little Neck...	Stonew'e clay.	62.66		18.09	.97	.79	....	2.33	....		....	H. T. Vulté, Anal.
Queens......	Glen Cove....	Stonew'e clay.	70.45		21.74	1.72	.24	.3	.5	....		....	H. T. Vulté, Anal.
OHIO:													
Columbiana...	East Liverpool	Yellowware clay........	42.28	18.02	24.12	1.46	.59	.68	2.42	7.77	.86	c. 1.2	Ohio. Geol. Sur. v, 1884, p. 1111.
Muskingum...	Zanesville....	Cookingware clay........	25.4	40.81	21.13	1.28	.51	.18	1.8	6.29	1.65	....	Ibid. vii, 1893.
Stark.........	Greentown...	Stonew'e clay.	72.26		19.23		....	....	....	6.63	.83	....	Ibid. v, 1884.
Summit......	Akron........	Stonew'e clay.	27.68	36.58	22.95	1.28	.45	.37	1.96	6.74	2.05	....	Ibid. vii, 1893.
PENNSYLVANIA:													
Beaver........	Oak Hill......	Yellow clay..	46.16		26.976	7.214	2.21	1.52	3.246	11.22		c .74	1897 Rep't. Pa. State Coll.

b. Determined as carbonate.

c. TiO_2

ANALYSES OF SLIP CLAYS.

State and County.	Town.	Remarks.	Silica.		Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water.		Miscellaneous.	Firm Names, Authority or Analyst.
			Combined.	Free.						Combined.	Free.		
MICHIGAN:	Rowley......	Slip clay.....	12.85	31.09	11.17	3.81	11.64	4.17	3.61	3.9	15.66 & CO_2	....	Ohio Geol. Sur. vii, 1893, p. 105.
NEW YORK: Albany.......	Albany......	Slip clay.....	14.33	46.26	12.46	5.79	6.84	3.28	4.39	4.36	1.46 & CO_2	....	Ibid.

ANALYSES OF KAOLINS.

State and County.	Town.	Remarks.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water.		Miscellaneous.	Firm Names, Authority or Analyst.
									Combined.	Free.		
CONNECTICUT:	Sharon.......	Washed kaolin	46.5	37.4	.8	tr.	....	1.1	12.49	....	....	H. Ries, Anal.
INDIANA: Lawrence.....	......	Non-plastic white kaolin	44.75	38.69	.95	.37	.3	.35	15.17	....	....	Ind. Geol. Sur. xx: p. 105.
MASSACHUSETTS: Hampden.....	Blandford....	......	52.03	31.76	tr.	tr.	.54	tr.	....	15.55	....	Tech. Quart., 1890.
MISSOURI: Bollinger......	Glen Allen....	Used for white ware.......	72.3	18.94	.4	.68	.39	.42	7.04	....	....	Mo. Geol. Sur. xi: p. 62.
Lawrence.....	Porter & Coates'Shaft, Aurora.....	Halloysite not worked.....	34.53	6.41	2.59	2.20	....	....	7.19	9.97	ZnO 37.23	Ibid. p. 566.
NO. CAROLINA:	Webster.....	Washed kaolin	45.7	40.61	1.39	.45	.09	2.82	8.98	.35	....	Bull. 13, N. C. Geol. Surv. p. 61.
	Webster.....	Crude kaolin.	62.4	26.51	1.14	.57	.01	.98	8.8	.25	....	Ibid. p. 62.
PENNSYLVANIA: Delaware......	Brandywine Summit.....	......	46.278	36.25	1.644	.192	.321	2.536	13.535	....	....	

PHYSICAL TESTS OF POTTERY MATERIAL.

Kaolin.—Kaolin, Harris Clay Company, Webster, N. C.[29] It works up with 42 per cent of water to a lean mass. Air-shrinkage, 6 per cent, fire-shrinkage, 4 per cent, making a total of 10 per cent. Average tensile strength 20 lbs. per square inch, with a maximum of 22. Incipient fusion 2300° Fahr., vitrification at 2500°, viscosity above 2700°. The clay burns white.

Kaolin, Arnold Land, Thayer, Davidson county, N. C.[30] 23 per cent water required to work it up to a lean mass, whose air-shrinkage was 3.2 per cent and fire-shrinkage 3.3 per cent, giving a total of 6.5 per cent. Average tensile strength, 13 lbs., maximum, 14 lbs. per square inch. Incipient fusion at 2300° Fahr., complete fusion at 2600°, viscosity at 2700°. Total per cent of fluxes, 2.36.

Kaolin, Glen Allen, Missouri. 23.2 per cent water required to work it up to a lean paste whose air-shrinkage was 4 per cent and fire-shrinkage 8.4 per cent, making a total shrinkage of 12.4 per cent; average tensile strength 12, maximum 14 lbs. per square inch. Incipient fusion at 2200° Fahr., vitrification at 2500°, viscosity not given.

Ball-clay.—Regina, Jefferson county, Missouri.[31] With 22.7 per cent of water it worked up to a very plastic mass whose air-shrinkage was 7.7 per cent, and fire-shrinkage 12.2 per cent, giving a total of 19.9 per cent. Average tensile strength 99, maximum of 108 lbs. per square inch. Incipient fusion at 1800° Fahr., vitrification at 2100°, and viscosity at 2400°. Total fluxes, 5.15 per cent.

Ball-clay, Edgar, Florida.[32] Very plastic and has an average tensile strength of about 65 lbs. per square inch. Burns very nearly white at the melting-point of orthoclase, which is about cone 8, and at this temperature gives a dense product with a total shrinkage of 15 per cent.

Ball-clay, New Jersey. When burned at cones 8 to 9 is of a yellowish white color and shows a total shrinkage of 14 per cent. This is quite plastic, but has a low tensile strength.

[29] North Carolina Geol. Survey, Bulletin 13.

[30] Ibid.

[31] Missouri Geol. Survey, vol. xi, p. 578.

[32] Langenbeck, Chemistry of Pottery, p. 101

Stoneware clay.—Stoneware clay, Waltman's, Barton county, Mo.[33] 19.2 per cent of water works it up to a rather lean mass whose air-shrinkage is 5.5 per cent, and fire-shrinkage 6.1 per cent, giving a total of 11.6 per cent. Average tensile strength 87, maximum of 98 lbs. per square inch. Incipient fusion at 2000° Fahr., vitrification at 2200°, viscosity at 2400°. Total fluxes, 2.42 per cent.

Stoneware clay, Calhoun, Henry county, Mo.[34] A very plastic buff-burning clay requiring 16.5 per cent of water to temper it. Air-shrinkage 5.5 per cent, fire-shrinkage 2.2 per cent, total 7.7 per cent. Average tensile strength 150 lbs., with a maximum of 168 lbs. per square inch. Incipient fusion at 2100° Fahr., vitrification at 2300°, viscosity at 2500°. Total fluxes present, 5.04 per cent.

Stoneware clay, Sammis's pits, Little Neck, near Northport, L. I., N. Y.[35] A yellow, sandy clay requiring 25 per cent of water to work it up and having fair plasticity. Average tensile strength 25, maximum 30 lbs. per square inch. Air-shrinkage 5.5 per cent, fire-shrinkage 6.5 per cent, giving a total of 12 per cent. At 2300° Fahr. nearly vitrified, and became viscous at cone 27. It burns buff.

Stoneware clay, Fern Bank, Lamar county, Ala.[36] A very plastic clay which works up with 32.6 per cent water. Air-shrinkage 10 per cent, fire-shrinkage 7 per cent, giving a total shrinkage of 17 per cent. Average tensile strength 152 lbs., maximum 185 lbs. per square inch. Incipient fusion at 1900° Fahr., vitrification at 2100°, viscosity at 2300°. Clay burns red and has 6.65 per cent total fluxes.

Pottery clay.—Pottery clay, Shirley's Mill, Fayette county, Alabama.[37] A very plastic clay with an air-shrinkage of 10 per cent, and fire-shrinkage of 4 per cent, giving a total of 14 per cent. Average tensile strength 106 lbs. per square inch with a maximum of 123 lbs. Clay burns to a yellowish-white body, which shows incipient fusion at 2000° Fahr., vitrification at 2200°, and viscosity at 2400°.

Calcareous clay, used in the manufacture of earthenware, from Ionia, Michigan.[38] A fine-grained clay which passes almost entirely

[33] [34] Missouri Geol. Survey, vol. xi.

[35] New York State Museum, Bulletin 35.

[36] [37] Alabama Geol. Survey, Bulletin 6.

[38] Michigan Geol. Survey, vol. viii, part 1.

FORMING CUPS ON JIG-WHEEL, BENNETT'S POTTERY, BALTIMORE.

The Friedenwald Co.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

through a 150-mesh sieve. It required 28 per cent of water to work it up, giving a mass of high plasticity. Air-shrinkage 8.5 per cent, fire-shrinkage 5 per cent. Average tensile strength 150 lbs. per square inch, with a maximum of 170 lbs. Incipient fusion at cone 05, vitrification at cone 1-2. Clay burns creamy white.

Alluvial pottery clay, near Blackburn, Catawba county, Delaware. A very plastic clay which worked up with 30 per cent of water. Air-shrinkage 12 per cent, fire-shrinkage 7 per cent, giving a total shrinkage of 19 per cent. Average tensile strength 148 lbs. per square inch. Incipient fusion 1950° Fahr., vitrification at 2100°, viscosity at 2250°.

METHODS OF MANUFACTURE.

Certain steps in the manufacture of pottery are common to all grades of ware, but the higher the quality of the product the more complicated usually is the process. The different stages in the manufacture of pottery are preparation, tempering, molding, drying, burning, glazing, decorating and burning. The preparation of the clay consists either of washing or weathering and has already been referred to in detail (see page 270). For tempering, several forms of machine may be used. One of these is the chaser-mill, which consists of a circular iron pan in which there revolves a frame with two heavy iron wheels, whose diameter may be from 30 to 36 inches. As this frame revolves, the wheels, by means of moving back and forth between the center and circumference of the pan, grind the clay. The clay is charged into the pan, water is added and by the action of the wheels ground and cut up and mixed in from one to two hours. Such a machine is very thorough in its action but consumes much power. It is sometimes used for stoneware clays.

Wet-pans are sometimes used in the preparation of pottery clays, where their action is the same as has already been described under bricks.

Pug-mills are also at times used in pottery manufacture, the form most commonly employed in potteries being a vertical one.

Molding.—Pottery may be molded in four different ways—turning, jollying, casting and pressing.

The clay after coming from the presses is first wedged, that is, a lump of the desired size is cut in two by a wire, the two halves united by bringing them down on the table with much force, the piece cut again, the two halves once more united, and so on, the object being to subject the clay to a kneading action, whereby the air bubbles are eliminated.

This operation is accomplished in many European factories by a kneading machine, which consists of a circular table about 6 feet in diameter, whose upper surface slopes outward. On this are two conical rolls, 20 to 30 inches in diameter, and about 8 inches wide. These rolls have corrugated rims, and are attached to opposite ends on a horizontal axis, having a slight vertical play. The clay is laid on the table and as the rolls travel around on it the clay is spread out into a broad band. A second axle carries two other pairs of rolls of the same shape but smaller size, which travel around in a horizontal plane. These rolls press the band of clay together again. In this way the clay is subjected to alternating vertical and lateral pressure and all air spaces are thus thoroughly closed. The rolls make 10 to 12 revolutions a minute, and a machine kneads two to three charges of 350 pounds each in an hour.

TURNING.—This is done on a rapidly revolving horizontal wheel. The potter takes the lump of clay, places it on the revolving disk, and after wetting the surface with a slip of clay and water, gradually works the mass up into the desired form. After being shaped, the object is detached from the wheel by running a thin wire underneath it and it is set aside to dry. Crocks, jugs, and similar articles are turned. This is the method almost invariably employed for molding earthenware and frequently employed in forming stoneware articles. An expert potter is able to turn jars of very large size.

JOLLYING OR JIGGING.—This is a more rapid method than turning and the clay to be used for this purpose is tempered to a much softer consistency. The jolly is a wheel fitted with a hollow head to receive the plaster mold, whose interior is of the same shape as the exterior of the object to be molded. A lump of clay is placed in the revolving mold and is gradually forced up around the sides of the latter

VIEW SHOWING METHOD OF SHAPING WARE BY PRESSING.

by means of the fingers. A metallic arm, or template as it is called, is then brought down into the mold and serves to shape the surface of the interior of the object. Cups, crocks, jugs, pitchers and even wash-basins can be molded in this manner. Articles with tapering necks are generally jollied in two parts, which are subsequently cemented together with slip. Handles are generally stamped out separately and subsequently fastened on the article.

A modification of jollying, used for making plates and saucers, consists in having a plaster mold whose surface has the same shape as the interior of the object to be molded. The potter's assistant takes a piece of clay of the desired size and pounds it into a flat cake, called a "bat," which is laid on the mold; he then shapes the other side or bottom of the plate by pressing a wooden template of the proper profile against it as it revolves.

Ewers and vessels of oval or elliptic section are usually made by means of sectional molds, consisting of two or three pieces whose inner surface conforms to the outer surface of the object to be molded. A slab of clay is laid in each section and carefully pressed in. The mold is then put together and the seams carefully smoothed with a wet sponge. After drying for a few hours the parts of the mold are lifted off. Clocks, lamps, picture-frames, water-pitchers, and many other articles of a hollow nature are molded in this manner.

Casting.—Casting consists in pouring a slip into a porous mold, which absorbs some of the water, and causes a thin layer of the clay to adhere to the interior surface of the mold. When this layer is sufficiently thick, the mold is inverted and the remaining slip is poured out. After a few hours the mold can be removed. This method is extensively used in making thin porcelain ornaments; many white earthenware objects can be formed by the same process. Much of the success of molding depends on the proper consistency and composition of the plaster mold.

Drying.—The ware, after it has been molded, is usually set aside on shelves in steam-heated rooms to dry. From this point on the method of manufacture varies somewhat, depending on the kind of ware that is to be produced.

Glazing stoneware.—Stoneware is most commonly glazed either with salt or by means of slip clays. Slip clays, which are really natural glazes, are very impure, easily fusible clays. The clay is mixed with water to the consistency of cream, and the ware before burning is either dipped into this slip or the slip is put on the ware by a brush.

The most desirable thing in a slip clay is that it shall fuse at a low temperature, form a glaze of a uniform color which will not crack or craze. Many fine-grained, impure clays fulfil the first requirement, but are seldom able to comply with the second and the third conditions.

Slip clays have been supplied to a considerable extent by several different states, but the most important and the best thus far used is obtained from the Champlain deposit at Albany, New York. This which does not crack. It not only works well by itself, but gives good results when mixed either with other clays or with artificial fluxes.

The following analysis, made by H. H. Griffen,[39] gives:

Silica	17.02
Alumina	14.80
Ferric oxide	5.85
Manganic oxide	.14
Lime	5.70
Magnesia	2.48
Potash	3.23
Soda	1.07
Phosphoric acid	.15
Water	5.18
Moisture and carbonic acid	4.94
Sand	38.58
Total	99.14

Tests made by the writer showed the following physical characters: Sample from the bank of the Brockway Brick Company worked up to a sticky but not highly plastic mass with 29 per cent of water. The bricklets showed an air-shrinkage of 5 to 6 per cent. The tensile strength of air-dried briquettes was 75 to 90 lbs. per square

[39] Clay Worker, xxviii, p. 178.

MOLDING OF SANITARY WARE, BENNETT'S POTTERY, BALTIMORE.

inch, but some reached 120 lbs. The clay also gave .2 per cent of soluble salts.

In burning, the clay turned red, with increasing depth of color as the temperature was raised, and at viscosity passed to a brownish glass. Incipient fusion occurred at cone 05 with a total shrinkage of 8 per cent. Vitrification occurred at cone 04 with a shrinkage of 15 per cent. Viscosity took place at cone 01.

For many years the slip has been used as a glaze without the addition of any artificial fluxes, for attempts in this direction had always been without success. A number of experiments were made by Mr. Griffen to determine in what manner it was possible to lower the fusibility of the slip clay and make it run more easily without destroying its richness of color. The addition of lead alone gave a transparent and greenish colored glaze, which showed a tendency to blister; alkalis added alone gave the same result. It is, therefore, necessary to add other materials with the lead. Good results were obtained by adding iron alone, but the combination of chromium, manganese and iron produced the best effect. The chromium, Mr. Griffen finds, takes from the iron its tendency to run into greenish and yellowish tints. The best form in which to introduce the chromium is as chromate of lead, this giving the finest color effect; but as an excess of this sort also has a tendency to cause blistering, it is well to add some of the chromium in the form of chromate of iron.

The following recipe is for a moderately low-heat glaze, the variation being for different conditions:

Albany slip clay	63.30	to	70.00
White lead	25.30	"	17.00
Flint	6.30	"	7.00
Oxide of iron	.72	"	.79
Oxide of manganese	.56	"	.91
Chromate of lead	1.27	"	1.40
Chromate of iron	.67	"	.73
Oxide of zinc	1.88	"	2.07

Artificial glazes are used to some extent on the better grade of stoneware made at the present day.

Stoneware is sometimes coated with a slip of white clay.

[40] Clay Worker, xxviii, p. 178.

Burning of stoneware.—Stoneware is commonly burned in round, or less commonly, rectangular, kilns of up-draft or down-draft pattern. The articles are piled on top of each other till the kiln is filled, but they are set in such a way as not to interfere with an even draft throughout the kiln, and the larger pieces are placed at the center. If both salt-glazed and slip-glazed wares are burned in the kiln at the same time the latter have to be protected from the salt vapor in some way.

The time of burning depends partly on the size of the kiln and partly on the clay. It may be as short as 30 hours or as long as 90.

The temperature attained in burning stoneware also depends on the clay. Experiments made in Ohio show that the temperature ranges from about 1850° to 2000° Fahr. Other experiments made by the writer indicate that in the case of the New Jersey semi-fire-clays the temperature in stoneware kilns reached 2300° Fahr. at times.

Glazing white earthenware and porcelain.—In this grade of ware the glazing and burning are not done in one operation, as in the case of the stoneware, but on the contrary, the ware after molding is first burned to a comparatively low temperature, after which it is dipped in the glaze and burned a second time. In the case of white earthenware the temperature of the second burning is lower than that of the first, while in the case of the porcelain it is higher. The production of a glaze on the surface of either porcelain or earthenware, free from the numerous defects to which such materials are very liable, is often attended by considerable difficulty.

The glaze on pottery consists of a fusible mixture which is applied to the surface of the ware, either when it is still in a green state or after burning. In the burning, the ingredients of the mixture unite during fusion and cover the surface with an impervious, glassy coat.

Pottery glazes are generally of two kinds, raw or fritted. The former consists usually of some mixture of metallic oxides, which is sprayed on the surface of the raw clay. In the case of the latter, the ingredients of the glaze are first fused together, forming what is known as a frit, the frit being then ground very fine and mixed

with water, this mixture being applied to the surface of the green ware. It is especially necessary to prepare such a frit when the glaze contains any soluble salts, the object of the fritting being to render these salts insoluble. The fritting is usually done in a special furnace, which has the bottom sloping toward one point, so that the melted material can be run out into a tank of water at the proper time. Certain frits, either on account of the difficulty with which they flow on melting or owing to the corrosive action they exert when fused, cannot be melted in the furnace, but are fused in a special crucible or sagger.

The proper preparation of the glaze often requires much skill and experience; for the production of a uniform coating of glaze on the surface of the ware is influenced by many different things, such as the degree of porosity of the ware when glazed, the cleanliness of the surface to be coated, the consistency of the glaze, etc.

If the density of the body is too great, or there happens to be a film of dust or fat on the surface, the glaze is likely to contract into drops during the burning. If the glaze is too refractory, or the kiln fire is not hot enough, the glaze will not be homogeneous, but show little dots and pin-holes. A frequent fault is the tearing or springing off of the glaze, which is due to the glaze and the body having different coefficients of expansion. If that of the glaze is greater the body is likely to tear, whereas if the reverse is true, the glaze spalls off. It may be said in general that with an increase in the amount of fluxes the coefficient of expansion of the glaze increases, while it decreases with the amount of acids. The coefficient of expansion may also be diminished if the percentage of boracic acid in the clay is increased at the expense of the silica. The amount of alumina exerts but little influence on the expansion or contraction of the glaze, but a small percentage of alumina prevents glazes which are poor in alkalis from becoming opaque.

The tenacity of adherence of the glaze to the body depends on the composition of both and also on the temperature of the kiln. In general terms, the power of the body to carry a glaze without causing it to crack is influenced by its rational composition, its degree of

plasticity, the fineness of the quartz grains which it contains, and the temperature at which it is burned.

Burning white earthenware and china.—This is done in saggers, which are oval or cylindric receptacles about 20 inches in diameter, 8 inches in height, with a flat bottom. The saggers are filled with the pieces of the unburned ware and are set one on top of the other, so that the bottom of one forms a cover for the one below it, the joint between them being closed by means of a strip of soft clay. The use of these saggers is to protect the ware from the smoke and gases of a kiln fire, which would tend to discolor it.

The requisite of a sagger clay is that it stand slightly more heat than the ware placed in it. Saggers are generally made from plastic, refractory clay, with as great an admixture of grog (ground up fire-brick or old pottery) as possible, but an excess of the latter is deleterious. The color-burning properties of a sagger clay are of little importance. Saggers are made in various ways, sometimes being turned on a wheel, or again being formed in plaster molds, or around wooden forms. In Germany metal forms are now mostly used, because they permit the working of a stiffer mass, and, the clay containing less water, the saggers after molding shrink and tear less, while in addition they dry more quickly. The interior of the sagger is frequently coated with a slip of kaolin and quartz, in order that the ware may not receive any discoloration from this source. When complicated forms are placed in the sagger the overhanging or greatly projecting portions are supported by pieces which have the same composition as the ware itself, so that in burning the shrinkage of both will be the same.

The proper placing of the ware in the kiln as well as in the saggers is a matter of great importance.

The condition of the fires in the burning of porcelain or earthenware has to be taken into consideration. In the burning of the spar china from redness to the point of vitrification it is desirable to have the fire reducing in its action, while above this point it should be neutral or weakly oxidizing. In using coal which contains pyrite, if the fire is oxidizing, sulphuric acid is set free; and this tends to

combine with any lime carbonate or alkalis which the glaze may contain; the lower the temperature of the kiln the more rapid this union, for the lime and alkalis will unite with the sulphuric acid as long as they have not entered in combination with the silica of the glaze. When the glaze has once melted, the danger that this will take place is far less. If the gases are reducing, any sulphate salts formed are broken up and sulphurous acid gas escapes. If the glaze particles have not yet been thoroughly fused the gas just mentioned escapes without causing any trouble; but, if the fusion has already occurred, blistering or scaling of the glazed surface results.

When a kiln full of ware is finished, the material at times has to be sorted, as it seldom happens that all the ware drawn from the kiln is perfect. The sources of flaws in the burned ware may be either faults in the body or bad firing.

In connection with body faults: the more plastic and fine-grained the clay mixture used, the quicker it shrinks in drying; masses which are fat shrink more than those which are rich in fluxes, such as feldspar. The size of the quartz and feldspar grains is of importance, for, if they are in the form of fine powder, they are not very plastic, but if ground extremely fine they develop a certain amount of pastiness, and this is accompanied by an increased shrinkage. If the clay mixture was not properly worked, or was too soft, or the thickness of the molded object is not the same throughout, or the mechanically combined water is not evenly distributed through the material, the ware is very likely to warp in burning. The shrinkage may also be uneven if the pressure exerted by the molder is not uniform, and cracks occur when the molded piece is stronger on one side than on the other. Flaws, such as air-bubbles, appear only when the ware is burned.

Firing errors are usually due to too quick heating or cooling. If cracks are caused in the early part of the burning they increase as the firing proceeds. Cracks formed in the body as a result of too rapid cooling are not generally seen by the naked eye, but the ware produces no ring when struck. Another cause of cracking is an uneven temperature on the two sides of the object. Over-burning

as well as under-burning of porcelain tends to produce fine cracks in the body.

The glaze is also a source of much worriment to the manufacturer. It should of course have the same coefficient of expansion as the body to which it is applied. If under-burned, the glaze will not appear thoroughly glassy because of the fine cracks developed, but if over-burned, a chemical action is likely to take place between the glaze and the body and the former absorbs elements of the latter, altering its composition and consequently its properties. This over-burning of the glaze is the principle used by the Chinese to produce their celebrated crackle ware.

Kilns.—The type of kiln used depends on the ware, the temperature to be obtained, and the fuel used.

In this country a round, vertical kiln is generally used for both the first and second burning. The first burning, which is known as the biscuit burn, is done at a lower temperature. The second firing is done in a similar kiln, known as the Glost kiln. After this ware has been burned with a glaze on it, it is sometimes decorated and then fired a third time in what is known as a muffle kiln.

The two points necessary in a kiln are, first, equal distribution of heat; and secondly, economy of fuel, with a development of the maximum heat.

Most of the kilns used are down-draft, and in these we get a more complete combustion, for the reason that the air and gases must follow a longer path, and consequently get a better chance to mix. The continuous type of kiln is little used in this country, though it has been used with marked success abroad for the burning of both white earthenware and porcelain.

METHODS OF DECORATION.

These seem to deserve special mention, as in many cases they form an important and distinct branch of the pottery industry.

Decoration may be imparted to a ware in three ways: (1) by the production of a raised design; (2) by covering the wares with a solid color; and (3) by the decoration of the surface with various designs, applied to the ware in one way or another. Common red earthen-

CARRYING SAGGARS OF WARE INTO KILN FOR BURNING, D. F. HAYNES AND SON, BALTIMORE.

ware seldom receives any decoration, though this has been decorated more within the last year or two. Stoneware, yellow-ware and Rockingham ware often have the surface ornamented with a raised design, which is imparted to the article in molding it. Stoneware is often decorated under the glaze with crude designs made by tracing the figure with a dull point and some coloring matter, which remains in the depression of the design. Yellow-ware is frequently ornamented with bands of various colors.

In majolica the coloring materials are mixed directly with the glaze.

It is the decoration of the white earthenware and china, however, that calls forth the ingenuity and skill of the potter. White wares may be decorated either over the glaze or under it. In the former the decoration is applied after the glaze has been put on and fired; in the latter the decoration is put on the biscuit ware, then fired, then the glaze applied and the ware fired again.

The advantage of underglaze decoration is that it is more durable, the decoration being protected by the glaze, and oftentimes the effect produced is prettier than when the colors are applied on the glaze. The number of colors which can be used in underglaze decoration is limited, as they have to withstand the effect of the heat required to fuse the glaze. The colors which can thus be used are blue, brown, green and yellow. It is on this account that hard-fired porcelains have their delicately tinted decorations applied over the glaze. Pink, for instance, has to be applied in this way, and so does gold.

All designs and colors were formerly applied by a brush, but the prevalent method now is by printing. The design is engraved or etched on a copper plate; the reversed print is then made on specially prepared fine paper. This is then applied to the piece of pottery to be decorated, either on the glaze or on the biscuit ware. The paper is carefully rubbed so that every portion of it shall come in contact with the surface of the ware, and it is then allowed to stand for a while, when the paper is removed, leaving the design on the ware. This is then gone over with colors and the design filled in. The decoration is then called a "filled print." The amount of "printed" ware turned out annually is very great.

Raised goldwork, often seen on wares, is made by painting the design with a yellow paste overglaze, firing in the decorating kiln, and then covering with gold and firing again.

Under-glaze colors are fired at a sufficient temperature to drive off the oil. The over-glaze colors are usually fixed in a muffle kiln in which the temperature reaches between 900° and 1000° Fahr.

Minor Uses of Clay.

Aside from the main use of clay for the manufacture of those products whose successful production depends on the property of plasticity in the raw material and its conversion into a rock-like product when burned, there are a number of other applications which are less important, but still should not be passed over without some brief mention. A minor use for clay is found in the manufacture of Portland cement, mineral paints, ultramarine, in clarifying oil, fulling cloth, filling paper, adulterating food and in polishing and abrasive agents.

PORTLAND CEMENT.

Portland cement is made from a mixture of clay or shale with some form of carbonate of lime, such as limestone, marl or chalk. The important ingredients of it are silica, alumina and lime, of which the first two are supplied by the clay constituents and the third by the calcareous one. Natural Portland cement is seldom found, and artificial mixtures therefore have to be employed. Since a report dealing especially with this subject is to be issued by the Survey in the near future, it is not necessary to go into a detailed description of it at the present time, and all that is necessary is to point out the fact that Maryland contains an abundance of both clays and shales which could be used in the manufacture of Portland cement. This is all the more true for the reason that beds of limestone of favorable composition are plentifully found within the limits of the State and often near to the outcrops of clay shale. Below are given a series of analyses of clays or shale used in the manufacture of Portland cement at different localities in the United States, and following this a table of analyses of Maryland clays and shales.

DECORATING ROOM, D. F. HAYNES AND SON, CHESAPEAKE POTTERY.

COMPOSITION OF CLAYS USED FOR PORTLAND CEMENT MANUFACTURE.

Locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Alkalies.	Moisture.	Water.	Misc.
Glens Falls, N. Y.	55.27	28.15		5.84	2.25				SO_3 .12
Warners, N. Y.	40.48	20.95		a25.80	a .99			b 8.50	
Sandusky, O.	64.70	11.90	9.90	.90	.70			b11.90	
Yankton, S. Dak.	57.98	18.26	4.57	1.75	1.83			b12.08	SO_3 1.28
Arkansas	65.12	19.05	7.66	.34	.31			b 6.12	
Wellston, Ohio	69.49	16.42		2.29	.78				
Stroh, Ind.	56.54	19.43	4.83	7.27	3.05				
Bertrand, Mich.	59.36	10.01		a23.80	2.40	.58		2.05	SO_3 1.71

a. In the form of carbonate. b. Includes organic matter.

MARYLAND CLAYS AVAILABLE FOR PORTLAND CEMENT MANUFACTURE.

Locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Alkalies.	Ignition.
Pleistocene clay, Bodkin Point	69.40	19.70	2.00	.20	.60	.62	7.85
Tertiary clay, Upper Marlboro	58.60	28.71	3.32	.40	.35	.63	8.90
Arundel clay, nr. Curtis Bay Jcn.	59.70	27.00	2.10	.60	.52	1.96	8.20
Conemaugh shale, n. of Frostburg	51.05	28.60	3.75	3.80	1.24	.50	10.85
Allegheny shale, Gannon's Drift, n. of Westernport	56.50	22.90	6.37	1.60	1.58	1.60	10.00
Jennings shale, Queen City Brick Co., Cumberland	68.30	17.50	4.00	.80	.65	3.10	5.10

From a comparison of the above it is easily seen that the Maryland materials closely resemble many of those which are used for cement manufacture in other localities.

The use of Portland cement is expanding enormously, so that the demand for it is very great, and on account of the fact that there are but few Portland cement factories in the Southern States, the trade

outlook for any works that might be started in the State of Maryland is extremely bright.

MINERAL PAINT.

Under this term there are grouped those clays and shales which are homogeneous in their color and usually of a red or other bright tint, so that when ground to a fine powder and mixed with oil they form an excellent coloring material.

Ocher, which is a fine-grained ferruginous clay, is one of the commonest forms of mineral paint. It is found at a number of points in Maryland. A bed of red mineral paint is often found at the base of the Raritan formation, and another one at the base of the Arundel. The former is well shown in the pits of the Washington Hydraulic Pressed Brick Company, one-half mile south of Harman, on the Pennsylvania Railroad, while the latter is worked in the pit of F. Link, on the Shell road, about two miles south of Baltimore.

The residual clay formed from the ferruginous limestone along the base of Catoctin Mountain on the west side of the Frederick Valley has also been worked quite extensively for mineral paint in past years, but the plant is now inactive. These clays find their richest development at Catoctin Furnace, a few miles south of Thurmont, where they have been worked for iron, the more earthy clay left after the washing of the ore serving as paint material in the form of ochre, umber and other colors. The clays are both ferruginous and manganiferous in various states of oxidation. By careful sorting, mixing, calcining, or treatment with chemicals it has been possible to get almost all natural shades, as well as green, blue and chrome yellow.

Mineral paints are extensively used for painting wooden surfaces. Their value depends partly on the shade of the raw material, its fineness and the percentage of oil which will be required to mix it up in order to give a fluid of the proper consistency.

FULLER'S EARTH.

Fuller's earth is a clay-like material which is used sometimes for fulling cloth (that is, removing the grease from it), and more extensively at other times for clarifying either mineral or vegetable oils.

In appearance it closely resembles ordinary clay; at the same time it differs from it in usually having a low plasticity, a greater percentage of chemically combined water as compared with the amount of alumina in it, and in possessing certain peculiar physical properties not yet well understood which tend to remove the impurities from oils that are filtered through it. Deposits of true fuller's earth have not yet been discovered in Maryland, but there is absolutely no reason why they should not exist. There is in the Patapsco formation a white, sandy, semi-refractory clay which is often spoken of as fuller's earth but which is not one at all. On account of its absorptive properties for grease, fuller's earth has also been used in the manufacture of certain soaps which are used for removing grease and printer's ink stains. The commercial value of fuller's earth cannot be determined by analysis, but has to be found out from actual tests made with both mineral and vegetable oils, for a fuller's earth which may be excellently adapted for clarifying one kind of oil is sometimes absolutely useless for treating the other kind. Earth which is used for fulling cloth may also be absolutely useless for purifying or filtering oils.

PAPER-FILLERS.

Clay is one of the materials used for filling paper, and for this purpose is mixed with the pulp during the process of manufacture, so that the fibers shall take up certain amount of the clay particles within their meshes. Clays which are used for manufacturing paper should not only be practically white for use in the higher grades, but they must also be very free from grit. For paper-filling the very best quality of fine white kaolin or sedimentary clay is used, the material being first carefully washed. Paper clays have been dug at one or another point in the Coastal Plain region of Maryland and no doubt many of the lenses of white, fine-grained fire-clay found in both the Patapsco and the Patuxent formations might serve well for filling paper (see detailed description of clays of these formations).

FOOD ADULTERANTS.

This use of clay is evident, it being used to adulterate food products which should be made from materials which the clay resembles

in color and which are used either in the powdered condition or caked form.

ULTRAMARINE MANUFACTURE.

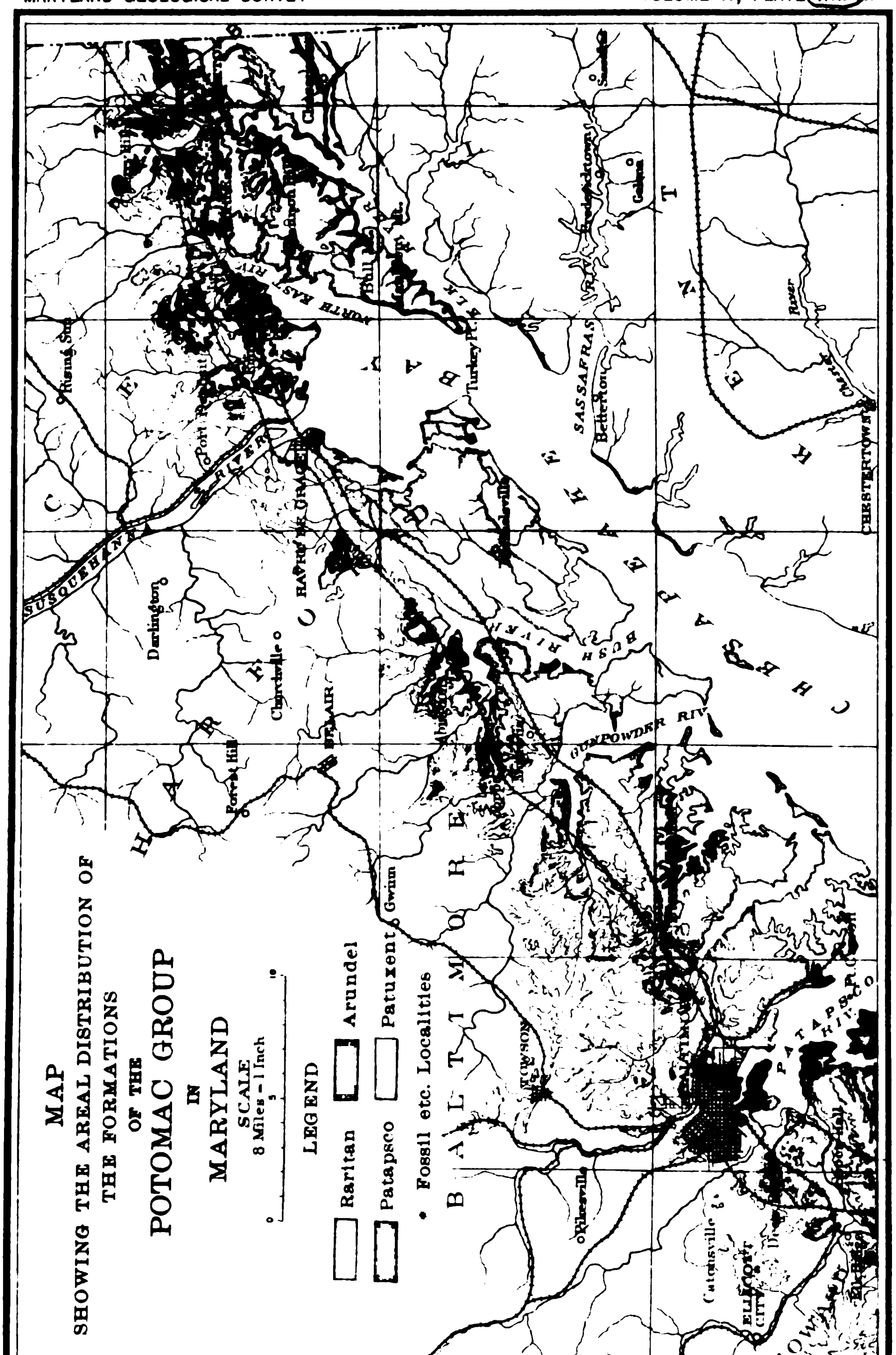
Fine-grained white clays are used to some extent in the manufacture of ultramarine. They should, for this purpose, be low in iron and lime and also free from an excess of silica.

POLISHING AND ABRASIVE MATERIALS.

Clays often exert a polishing and abrasive action on account of the very finely divided grains of sand which they contain. The well-known bath brick which is such an extensive domestic scouring material for steel utensils is made from a fine-grained, siliceous clay deposit along the banks of the Parrot river, England. There is absolutely no reason why the same material should not be found in the Coastal Plain region of Maryland; especially, perhaps, in the Patuxent or Columbia formations, since both of these contain many sandy beds.

Another abrasive use of the clay is as a cementing material in emery-wheels, the wheels being made up of a mixture of emery grains and a clay bond. After molding, the wheel is put into the furnace and burned so that the clay on fusing slightly forms a hard, durable and firm cement for the emery grains.

 XXX/X2



Geology by Arthur Bibbins

A. HOEN & CO. BALTIMORE

THE CLAYS OF MARYLAND.

Geological Distribution and Character.

The formations found in Maryland range all the way from the Algonkian to the Pleistocene. These formations and their order of succession are represented in the following table:

	Formation.	
CENOZOIC.		
Pleistocene	Talbot.	Columbia group.
	Wicomico.	
	Sunderland.	
Neocene	Lafayette.	
	Chesapeake.	
Eocene	Nanjemoy.	Pamunkey group.
	Aquia.	
MESOZOIC.		
Cretaceous	Rancocas.	
	Monmouth.	
	Matawan.	
	Raritan.	Potomac group.
	Patapsco.	
Jurassic (?)	Arundel.	
	Patuxent.	
Triassic	Newark.	
PALEOZOIC.		
Permian (?)	Dunkard.	
Carboniferous	Monongahela.	
	Conemaugh.	
	Allegheny.	
	Pottsville.	
	Mauch Chunk.	
	Greenbrier.	
	Pocono.	
Devonian	Hampshire.	
	Jennings.	
	Romney.	
	Oriskany.	
	Helderberg.	
Silurian	Salina.	
	Niagara.	
	Clinton.	
	Tuscarora (White Medina).	
	Juniata (Red Medina).	
	Martinsburg.	
	Shenandoah (upper part).	
Cambrian	Shenandoah (lower part).	
	Antietam.	
	Harpers.	
	Weverton.	
	Loudoun.	
Pre-Cambrian	Igneous and Metamorphic Rocks.	

The State can be divided into three topographic provinces, viz.: the Coastal Plain, the Piedmont Plateau, and the Appalachian Region.

The Coastal Plain area in which the Pleistocene, Neocene, Eocene, Cretaceous, Jurassic, and some of the Algonkian formations occur, forms a tract extending from the south shore of Raritan Bay in New Jersey, where it is 15 or 20 miles wide, southward with ever increasing width until in Georgia it has a width of nearly 150 miles.

In Maryland the Coastal Plain is a broad, level stretch cut into here and there by streams from the Piedmont Plateau, and also local ones. The Plain is bounded on the southeast by the Atlantic Ocean and on the northwest by a line passing from Wilmington through Baltimore to Washington. It comprises about 5000 square miles, or somewhat over half the land area of the State.

Although quite flat, still the numerous small streams which dissect it afford many excellent exposures and facilitate greatly the study of both the geologic and economic features of the region.

Chesapeake Bay extends nearly the full length of it from north to south.

The Piedmont Plateau region extends from the western boundary of the Coastal Plain to the Appalachian mountains.

The Piedmont Plateau is a region of somewhat greater elevation than the Coastal Plain which borders it upon the east, but stands in marked contrast to the high ranges of the Appalachian Region upon the west. It is characterized by a broken, hilly country with undulating surface, but with few mountains of conspicuous altitude or great extent. The region is crossed by numerous rivers which have their rise in the high mountains to the west, while many smaller streams and tributaries have their sources within the area. Within this area the clays are obtained partly from the Paleozoic and to a small extent from the Mesozoic and pre-Cambrian formations. When obtained from the first two the material is usually shale. The third yields residual clays which may often be of good quality. Where the Paleozoic rocks have been metamorphosed they are seldom of any value to the clay worker in their unweathered state.

In the Piedmont Plateau the eastern region is composed of metamorphic rocks, which disappear under the sediments of the Coastal Plain. In the western half the rocks are less thoroughly crystalline.

The eastern ones, possibly of pre-Cambrian age, cross Maryland from the southeast corner of Pennsylvania, and the northern corner of Delaware in a general southwesterly direction.

The prevailing rock of this area is a gneiss, which enters the State from the north in a very wide band, completely surrounding the Delta Peach Bottom slate area, but contracting in width towards the Potomac. In places beds of marble are intercalated with the gneissic rock. The more massive gneisses vary considerably mineralogically, some being hornblendic and others micaceous. The exposures are rarely fresh, but on the contrary the rock has often broken down to a residual clay, which may at times be of considerable thickness. These residual clays are often ferruginous, at other times so free from iron as to be cream or white burning. The high-grade clays have been especially developed in Cecil county.

In the western Piedmont region the Cambrian and Silurian rocks cover considerable areas in Frederick and Carroll counties. The shales have usually been more or less metamorphosed, but the limestones have by their decomposition produced residual clays, which are worked around Frederick.

The Appalachian Region consists of a series of parallel mountain ridges composed of upturned Paleozoic strata. The Silurian rocks which are found west of the Cambrian formations constitute a portion of the Great Valley and unite with the Devonian in forming the Alleghany Ridges. Most of the beds have been but little metamorphosed.

In the western part of the State the Devonian shales reach a great thickness. They contain many important shale beds, as do also the Carboniferous rocks which underlie western Allegany and most of Garrett counties. The Devonian shales are worked at Cumberland for making paving-brick and the Carboniferous beds are employed at Mount Savage and Frostburg.

Since it is of importance to know which of the geological formations found in the State are the most likely to yield good clays in a considerable variety it has been deemed proper to take up a detailed discussion of the clays by formations. In another chapter the clays are also treated briefly by varieties, and cross references used in this connection, so that a person wishing to obtain information concerning a given kind of clay can easily do so.

The clays of Maryland are but little known, and consequently have been but little worked in many cases, therefore, two points have been borne in mind in this work, viz.: the location of the deposit in its relation to profitable working and its characters with reference to its uses.

A number of samples have been collected from the different formations, and tests have been made on them in the laboratory in order to demonstrate, as far as possible, their value.

THE PLEISTOCENE CLAYS.

Overlying different formations of the Coastal Plain region, and sometimes extending up on the rocks of the Piedmont region, is a mantle of sandy clay, loam and gravel, of variable thickness. These loams, which belong to the Columbia group, are very extensive, and seldom wanting. They are frequently employed in the manufacture of common brick, but not for any better grade of clay product.

The Pleistocene clays usually underlie terraces at no great elevation above the sea-level.

According to Dr. Shattuck the Pleistocene has been divided into three parts, viz.:

Group.	Formation.
Columbia	Talbot.
	Wicomico.
	Sunderland.

The Talbot is the youngest and often carries lenses of greenish-black clay, as at Bodkin Point, Anne Arundel county; in the cliff five miles below Cedar Point, St. Mary's county, and just above Cornfield Harbor on the Potomac river.

MARYLAND GEOLOGICAL SURVEY

SCALE
1:1,250,000. 20 Miles = 1 Inch
0 5 10 20 40 60

MARYLAND GEOLOGICAL SURVEY
WM. BULLOCK CLARK, STATE GEOLOGIST
1902

A. Hoen & Co., Lith. Baltimore.

The Wicomico seldom contains deposits of clay large enough to be of economic value.

The Sunderland, or oldest Pleistocene deposit, has clay beds which are typically exposed in the cliffs one-half mile north of Point of Rocks, Calvert county, and also in the vicinity of Poplar Hill Creek, St. Mary's county.

The Talbot does not as a rule exceed 45 feet in thickness, and the Wicomico is found from 45 up to 70 or 100 feet.

The Pleistocene clays are not used for anything except common brick.

Cecil County.—It will be seen by reference to the geologic sections in different parts of the report that the Pleistocene loams are persistent in extent, but not always very thick. Beginning at the northeastern end of the Coastal Plain excellent exposures are found in Cecil county. One of these is in the cut just north of Perryville station on the Pennsylvania railroad (49, Havre de Grace 9).[1] This deposit as exposed is at least twelve feet thick and the outcrop is not less than six hundred feet long. Because of its location along the track the material, or ware made from it could be easily shipped. The exposure is shown in Plate XLI, Fig. 1.

Underlying the terrace east of the town of Elkton are deposits of Columbia clays which have been used by the local brick plant.

Many beds of sandy Columbia clay overlie the Chocolate clays outcropping in the bluffs along the shore at the foot of Bull Mountain on the westerly side of Elk Neck (30, Elkton 7).

The Columbia clays, which are well exposed at Wilson's Beach, are similar in character to those which are found in the cut at Perryville. At one place in the former locality they are capped by a mass of

[1] The first number is the one given to the specimen tested at the time it was collected or entered in the notebook; the name indicates the topographic quadrangle and the succeeding number the particular section of the quadrangle in which the deposit occurs. The area included in one quadrangle is arbitrarily divided by two vertical and two horizontal lines into nine equal parts which are numbered from left to right across the quadrangle. Thus, (49, Havre de Grace 9) indicates that specimen No. 49, taken from the southeastern portion of the Havre de Grace quadrangle, showed the properties given. Additional information regarding the location of the deposits may be gained from the State Geologist.

limonite, which serves as a cementing material for the sand over the clay.

A very sandy deposit of what might be called loessoid clay occurs at Stump Point (5811, Havre de Grace 9). The material sometimes contains alum and is therefore spoken of in places as alum-clay.

While most of the deposits of Pleistocene clay in Cecil county are very silicious and best adapted to common brick, still in places the Pleistocene contains some good deposits of plastic clay, of different grades.

There is an important bed at the base of Bull Mountain (239, Elkton 7) where it forms a bluff 30 feet high with about 10 feet of stripping to the first bed.

The clay, which would do well for the manufacture of terra cotta, is a dark plastic material. Like many of the Coastal Plain clays it is rather sandy or, more properly speaking, silty in its nature, and contains scattered mica scales. When thrown into water it slakes rather slowly, yielding a mass of very good plasticity. In tempering the material 25% of water is required. The amount of fine grit in the clay can be appreciated from the fact that in washing but a mere trace remained on a sieve having 100 meshes to the linear inch while about 40% remained on a bolting cloth sieve of 150 meshes.

The air-shrinkage of the clay was low, being but 5%, while the average tensile strength was 123 pounds per square inch with a maximum of 134 pounds. In burning, incipient fusion occurred at cone 01, vitrification at cone 5. The clay burns to a good red color and shows a total shrinkage in vitrifying of 10%.

Its composition is:

ANALYSIS OF PLASTIC CLAY, BULL MOUNTAIN, CECIL COUNTY.

Silica	76.80
Alumina	15.00
Ferric oxide	2.50
Lime	.20
Magnesia	.44
Alkalies	.62
Ignition	5.15
Total	100.71

It would no doubt lend itself well to the manufacture of structural materials, terra cotta or floor tiles.

Following the shore from here southward towards Winslow's Point there are considerable quantities of clay outcropping at the water level which are very similar in their character to (239, Elkton 7) mentioned above.

A deposit of chocolate clay similar to that found at Shannon Hill, is also found at Stump Point in the same county (5804, Havre de Grace 9), but this one is of later age.

Harford County.—The Columbia sandy clays are abundant and show their normal characters. Exposures of an unusual variety were noticed by Mr. Bibbins at several points along the shore from Stone Point to Bush river. It is a tough, dense, brown clay, which is usually quite homogeneous, and has little overburden so that this fact, together with its location, should make it well worth examining by the clay-worker.

A fine-grained silicious clay, representing the loessoid type of the Columbia is found on the Davis estate south of Havre de Grace (8829, Havre de Grace 8). It is very similar to the loess so abundantly used in the West for the manufacture of common brick.

Baltimore County.—Here as in the other counties the Pleistocene deposits are usually found mantling the Potomac clays, especially at low levels. Thus around Baltimore the sandy Columbia clays are found at many points below 30 feet above sea-level, and are extensively used in the manufacture of common brick. They are usually very gritty, moderately plastic, and have sufficient iron oxide distributed through them to burn to a good red color. They are not at all refractory.

The Columbia formation can be said to underlie immediately the surface over most of the district southeast of the Philadelphia, Wilmington and Baltimore Railroad and from Bird river down to the Patapsco river.

There is an abundance of low-level Columbia clay at Ferry Point (53, Baltimore 8) which is used in the manufacture of brick at the yard of J. A. Allen & Sons (now yard No. 8, of the Baltimore Brick Company).

The Columbia clay is often rather sandy but nevertheless quite plastic and makes a good red brick. This same clay overlies the Patapsco clay in the district northeast of Sparrows Point, especially in what is known as Patapsco Neck (North Point 1). It is also found at other low-lying points in the county.

Anne Arundel County.—Here again the Columbia clays are not wanting, being well exposed, for example, at the old brick clay openings near Curtis Bay (8783, Relay 2). They are light gray in color with limonite stains and possess very fair plasticity.

An extended series of outcrops of Pleistocene and Raritan clays, of different varieties, associated with clays of earlier ages, is to be found along the western shore of Chesapeake Bay, from Bodkin Point southward.

Beginning at a point about ¼ mile south of the lighthouse on the point there is an exposure of clay in the bluff about 15 feet high and perhaps 500 feet long. The beach and the lower seven feet of the bluff are black, brownish, or bluish, sandy clay, with interbedded reddish and bluish white clay in places. Above the blue there is a five or six-foot bed of variegated clay which might perhaps be used in the manufacture of bricks. Along the shore there are also exposures of the stoneware clay (298, North Point 4), while interbedded with it in places is a sandy clay (299, North Point 4). The stoneware clay (298, North Point 4) is a bluish plastic clay and represents the layers of potter's clay which are interbedded with the beds of sandy plastic clay at that locality. The latter are represented by No. 299 (North Point 4). The tensile strength of this clay averages 132 pounds per square inch. The fire-tests indicate that the clay burns to a body well adapted to the manufacture of stoneware, the color of which is buff. Its behavior at several temperatures is as follows: at cone 03 the total shrinkage is 9%, and the color whitish; at cone 4, with a total shrinkage of 12%, and a buff color, a good, hard body is produced while at cone 10 the clay vitrifies with a total shrinkage of 16%. The outcrop of this clay is seen in Plate XLI, Fig. 2. Its composition is as follows:

FIG. 1.—PLEISTOCENE CLAY, RAILROAD CUT NORTH OF PERRYVILLE, CECIL COUNTY.

FIG. 2.—CLAY BEDS OF PLEISTOCENE, BODKIN POINT, ANNE ARUNDEL COUNTY.

Analysis of Stoneware Clay from Bodkin Point.

Silica	69.40
Alumina	19.70
Ferric oxide	2.00
Lime	.20
Magnesia	.60
Alkalies	.62
Ignition	7.85
Total	100.37
Total fluxes	3.42

The low iron causes the light color in burning, and the effect of moderately low total flux is shown by the high temperature required for vitrification. The silica is not excessive.

Overlying these clays which are of Raritan age is a second bluish clay of Pleistocene age. This is quite distinct from the preceding clays and occurs in large quantity in the upper part of the bank (45, North Point 4).

At a point one mile south of Bodkin Point on Chesapeake Bay (235, North Point 4) there are considerable outcrops of whitish, gritty clay with scattered limonite stains. As here exposed the bed is at least seven feet thick, with four feet of overburden, but it grades into a sandy clay to the northward, while along the beach-level there are outcrops of plastic blue potter's clay which are either underlain by or interbedded with the white material. This clay forms an exposure of considerable extent immediately along the shore, and owing to its promising appearance and important location from an economic standpoint it seemed desirable to look into its qualities.

The air-shrinkage of the material is moderate, being but 4%. In burning it develops a cream white color which would find much favor probably with some brick or terra cotta manufacturers. Another desirable point about it is that its fire-shrinkage is not excessive. Thus at cone 3 it is 5%, at cone 4, 6%, at cone 10, 7%. This is due partly to the grit in the clay and partly to its refractory quality, for at cone 10 it is still absorbent, while it does not become hard enough to resist scratching with the knife until about cone 5.

A little further south are exposed a number of tree trunks of cypress representing a buried forest of Talbot age still in place with the roots branching out through a bluish-gray clay. This clay be-

cause of the large amount of organic matter which it contains is of no value to the clay-worker. The occurrence is represented in Plate XLII, Fig. 1.

Again at the point about 200 feet south of the buried forest there occurs a drab and red mottled Raritan clay (248, North Point 4). The bed is at least 10 feet thick.

This mottled clay is not refractory, nor a potter's clay, but the slow manner in which it softens in burning, rather tends to point out its possibility for the manufacture of vitrified brick, even though its tensile strength is not so very high. Many paving-brick are made from shale whose tensile strength is no greater than that of this clay.

To the feel it is quite plastic, but required only 23% of water to mix it up. There is some fine grit in it, for when washed there remains 1% of sand on a 100-mesh sieve, and 4% on a 150-mesh sieve. The average tensile strength of the air-dried briquettes is 70 pounds per square inch, and the air-shrinkage was 5%. Incipient fusion occurs at cone 3, and vitrification at cone 8. The clay burns buff at cone 05 with a total shrinkage of 6%; pale red at 1, with 9% shrinkage; light red at 2, with no increase in the shrinkage; red at cone 6, with 11% shrinkage, and red at 8, with 13% shrinkage. It could also be used by floor-tile and pottery manufacturers. Located as it is, along the shore of the Bay, the shipping facilities are good.

Farther south from this point at locality 266 there is a very extensive exposure of Pleistocene clay which crops out in places over twelve or fifteen feet high. The material is readily recognized owing to the fact that it contains numerous bluish specks of the phosphate of iron or vivianite.

Still another outcrop of Pleistocene clay is located at a point along the shore of Chesapeake Bay, one mile south of the buried forest (300, North Point 4). It is a tough reddish clay, forming a bed from four to fifteen feet thick, with four to six feet of overburden.

This is a clay of good plasticity, slight grittiness and high tensile strength, the latter ranging from 160 to 180 pounds per square inch, the air-shrinkage of the bricklets being 8%. In working up the material 35% of water was required. The bricklets thus made burned to a good red color, and vitrified at a moderate temperature, but had a

rather high shrinkage. Incipient fusion occurred at cone 1 and vitrification at cone 4, the shrinkage at the former point being 15% and at the latter point 18%.

Owing to the excellent location of this material along tide-water it should be of considerable economic value and might perhaps lend itself to the manufacture of paving-brick, in which case it would need the admixture of some sand. Portland cement producers might also be able to use the material.

This clay (266, North Point 4) has certain good features, viz.: the deep red color to which it burns and the density which it shows when burned at a low temperature, although its excessive shrinkage is unfortunate. Its plasticity and dense burning character are such, however, that a leaner clay could undoubtedly be mixed in with it so as to make paving-brick.

There is also a large quantity of it available, where it crops out in a bluff along the shore of the Bay. The physical tests show it to be a gritty, slow-slaking, but not hard clay, of high plasticity, which took 40% of water to mix it up. The air-shrinkage was 11%. The average tensile strength of air-dried briquettes was 223 pounds per square inch, with a maximum of 250 pounds. Incipient fusion began at cone 05 with a total shrinkage of 16%; at cone 1, the total shrinkage was 20% and the color deep red. The clay vitrified at cone 2, with total shrinkage of 21%, and became viscous at cone 7. The vivianite, although so noticeable in the green clay, seems to exert no effect on the burned ware.

The location of the clays along the shore southward from Bodkin Point and the number of varieties exposed in the neighborhood suggested that their possible future usefulness warranted the testing of these clays on a larger scale at some manufacturing brick works now in operation. Accordingly large samples of the clay containing vivianite and a yellowish clay from the north end of the same bluff, together with samples of the gray sandy clay and its underlying mixed clay from the hill south of Mt. Winans were shipped to the Onondaga Vitrified Brick Company of Warners, New York.[1]

[1] A full report on the behavior of these clays tested by themselves or mixed in various ways may be found in the Addenda, pp. 500–503.

The tests made on the vivianite clay by itself showed that after it had been broken in a disintegrator and mixed in a pug-mill it would work smoothly in stiff-mud machines but that it must be handled somewhat carefully during the drying and burning. It burned to a good red color under ordinary conditions and to a deep brown when vitrified. Before this clay could be used in large ware it would be necessary to add sand to prevent excessive shrinkage.

The tests made on a mixture composed of equal parts of the vivianite clay and the yellow clay from nearby showed that it would burn to the same colors as the vivianite clay by itself and that it would form a strong dense brick showing little lamination which would be less tender during drying and burning. The tests on the yellow clay by itself showed that this could be pugged easily, worked to advantage with an auger machine and withstand rapid firing and drying. The burned product is of a beautiful red color and the clay would make a fine front brick. Neither of these clays by themselves or mixed together will apparently work as satisfactorily for paving-brick or hollow brick as clays from other areas nearby.

An additional outcrop (301, North Point 4) shows a gritty clay of low plasticity having a low tensile strength which ranged from 56 to 60 pounds per square inch. At cone 4 the total shrinkage was 10%, and the clay showed signs of incipient fusion. In order to test its refractoriness it was heated to cone 27 in the Deville furnace, at which point it became viscous. It burns to a buff color.

Pleistocene clay of very fine grain and fair plasticity occurs along the shore south of Indian Landing (8771, Relay 8). The clays, which are several feet in thickness, are practically at the same horizon as those found at Bodkin Point.

Howard County.—A short distance north of Savage Station on the Baltimore and Ohio Railroad, on the northern side of the Baltimore and Washington road, a deposit of Pleistocene clay has been opened on the Donaldson estate. Two types of clay occur. The first is a yellowish gritty clay, the second is a more plastic clay of grayish color. Samples of these clays have not been put through a complete series of tests but a preliminary examination shows that they could be used for vitrified brick if they were mixed in proper proportions. On the

FIG. 1.—PLEISTOCENE CLAYS ALONG SHORE SOUTH OF BODKIN POINT, ANNE ARUNDEL COUNTY.

FIG. 2.—BURIED FOREST OVERLAIN BY PLEISTOCENE CLAY, SOUTH OF BODKIN POINT.

south side of the same road is an old brick-yard which is no longer worked.

Prince George's County.—The Pleistocene clay deposits of Prince George's county are not of any special importance from an economic point of view, as the deposits capable of being utilized for brick or tile are quite local and not particularly valuable. The Pleistocene of this county is composed mainly of gravel and sand with occasional clay lenses and these are all covered with a loam cap. This surface loam is occasionally quite argillaceous and at times has been used in the manufacture of brick. The dark color indicates the presence of considerable organic matter.

The Sunderland and Wicomico formations contain very few workable clay deposits and at present none within the county is being utilized. The Talbot, however, contains much more clay, which is also of apparently better quality. The most extensive and valuable Pleistocene clay deposit of this county is of Talbot age and is located on the south bank of Broad Creek at its junction with the Potomac river. This is really the only deposit of Pleistocene clay in Prince George's county of any great importance. At this point the Talbot furnishes very good brick-making material. The deposit consists of a very compact clay varying in thickness from 10 to 16 feet. In places, it is mainly an impure kaolin and is used for terra cotta. Occasional pebbles of small size are present but not in large enough quantity to interfere seriously. Some brick are made at this place but most of the clay is taken to Washington on flat-boats and there used by the Washington Brick and Terra Cotta Company.

The Talbot formation along the west side of Anacostia river within the District of Columbia, at the extreme eastern part of the city of Washington, contains a capping of argillaceous loam which, from time to time, has been used in the manufacture of brick.

Southern Maryland Counties.—The clay deposits of Southern Maryland, which are included within the counties of southern Anne Arundel, Calvert, St. Mary's and Charles, have not as yet been worked to any great extent. The only brick-yard of importance is located in Calvert county across the cove from Solomons Island, but at the present time it has suspended operations. As there are vast

deposits of clay which can doubtless be used for the manufacture of brick and tile, lack of transportation facilities and of a ready market have alone been the cause of the neglect of these valuable natural resources.

The Wicomico and Talbot formations lie in great terrace-like surfaces beneath the Sunderland throughout Southern Maryland. They consist of clay, sand and gravel and usually their surfaces are composed of a clay loam which is of various colors from black to red but the browns and buffs predominate. It resembles in many respects the surface color of the Lafayette and Sunderland and doubtless can be utilized profitably here, as elsewhere, for brick and tile manufacture. In the Talbot, there are developed certain lenses of bluish-green clay which probably can be worked with profit. They are of the same age and are identical in appearance with the Bodkin Point clay described above. They occur from tide or a little below to 5, 10 or 15 feet above, and are usually buried beneath a thin cover of sand and gravel which would not seriously increase the expense of working. They carry plant remains in the form of peat beds and isolated stumps and also, at times, fossil shells, but these latter could well be removed without large expense. The most important of these clay lenses are: one-half mile northeast of Drum Point (Drum Point 8); one-quarter mile west of Drum Point (Drum Point 7); one-half mile south of St. Leonard Creek (Drum Point 4); one mile west of Cedar Point (Drum Point 8); five miles south of Cedar Point (Point Lookout 5); one mile north of Cornfield Point (Point Lookout 8); one-quarter mile south of Lovers Point (Leonardtown 8).

The Sunderland formation is developed in St. Mary's county as extensively as the Lafayette is in Charles and Prince George's counties and occupies the same relative position, that is to say, the divides. It resembles, likewise, the Lafayette both in color and in composition and locally could probably be used for the manufacture of bricks. The Sunderland formation is also well developed in Charles county but, although present in Calvert and Anne Arundel, it is frequently sandy and it is doubtful if it can be utilized to the same extent as elsewhere for brick-making.

Eastern Shore Counties.—The clay-working industries of the

Eastern Shore have never been extensively developed because of the local abundance of lumber for building purposes and because the scattered population is largely devoted to agriculture and oystering. The available clay beds of this area are confined almost entirely to the Wicomico and Talbot formations of Pleistocene age which consist of clay-loam, clay-sand or gravel, with a top cover of clay-loam. It is the latter formation which is most often used for the manufacture of brick in the different counties of the Eastern Shore. Many pits have been opened and brick-yards established near the larger towns, the most important being those at Centerville, Greensborough and Ridgely, Caroline county; at Cambridge and Vienna, Dorchester county; at Easton, St. Michael's and Tilghman's, Talbot county; at Salisbury, Wicomico county; at Crisfield, Somerset county; and at Berlin and Pocomoke City, Worcester county.

THE NEOCENE CLAYS.

The Neocene deposits of Maryland occupy a broad area in the eastern portion of the State, and consists of strata which attain a greater thickness than those of any other age represented in the Coastal Plain, with the possible exception of the Cretaceous. The deposits of this age have been divided as follows:

	Formation.
Neocene.....	Lafayette.
	Chesapeake.

The *Lafayette* formation consists of gravel, sands and clays which are very irregularly stratified and often change rapidly within narrow limits. Since these deposits seldom exceed 25 feet in thickness and usually show large admixtures of solid grains or pebbles, they are of little value to the clay-worker.

The Lafayette formation is developed extensively on the divides in Charles county. It forms here a buff-colored clay loam which resembles, in many respects, the Philadelphia brick clay of Pennsylvania which has been used so extensively in brick manufacture. It also resembles very closely the clay loam which has been used in the region of Trenton, Baltimore and Washington for the manufacture of bricks. In the other counties of Southern Maryland the Lafay-

ette formation is represented only as isolated outliers and as of little commercial importance.

The *Chesapeake* formation consists chiefly of sands and marls with only local developments of clay or diatomaceous earth.

In Southern Maryland the Chesapeake beds cross the country from northeast to southwest and form the most extensive group of deposits in the region. Lithologically they are divisible into two phases, a sandy phase and a sandy clay phase; of these two phases, the latter is the only one which possesses any economic possibilities. It is greenish-blue in color, carries vast quantities of fossil shells and is of unknown thickness. It is found developed all over Southern Maryland south of a line running from Herring Bay to the mouth of Piscataway Creek. Throughout Calvert county, the formation is extensively exposed in high bluffs along the Calvert Cliffs and with less conspicuous outcrops on the Patuxent river. In St. Mary's and Charles counties, this formation is buried under heavy deposits of sand, gravel and clay and does not form a conspicuous feature either along the surface or along the banks of either the Patuxent or Potomac rivers. It is, however, present and may be repeatedly seen in stream-cuttings where the surface cover has been carried away. These sandy clays have never been worked and it is probable that they are of no particular economic importance. They bear large quantities of iron and lime, the latter ingredient being largely increased by the great deposits of fossil shells. The sandy phase of the Neocene is predominant north of the Herring Bay-Piscataway Creek line but also is extensively developed in the country to the south of it and covers up, in a large measure, the underlying sandy clay deposits.

The sandy clay is most accessible along the banks of the Patuxent river and the Calvert Cliffs. Here, if it were found desirable to work the deposits, the material could be loaded directly on to boats without large expense. The abundance of shells and consequent lime in the clays of the Chesapeake formation render the deposits of little importance to the clay-worker.

The diatomaceous earth found at Pope's Creek on the Potomac, at the mouth of Lyons Creek on the Patuxent, and at Herring Bay on

FIG. 1.—PATUXENT RIVER AND WORKS OF NEW YORK SILICITE COMPANY, CALVERT COUNTY.

FIG. 2.—NEARER VIEW OF WORKS.

the west shore of the Chesapeake may prove of some importance. These deposits have long been known and are sometimes referred to as Richmond earth, infusorial earth, Tripoli or silica. The material has been opened up at Lyons Creek on the Patuxent river, by the New York Silicite Company (283, Prince Frederick 1). Silica in the form of quartz and also white sand is much used by pottery manufacturers, and as explained in the chapters on pottery manufacture, should not only possess refractoriness but also be free from color when burned.

The material from Lyons Creek (283) is used chiefly for abrasive purposes, but since the earth is supposed to be made up of the silicious cases of diatoms, it was assumed that it must be fairly refractory unless it contained impurities. With this idea in view a sample of it was tested at cone 27 in the Deville furnace with the result that the material fused to a drop of brownish glass, indicating clearly its non-refractory character.

The deposit and works are illustrated in Plate XLIII, Figs. 1 and 2.

THE EOCENE CLAYS.

The Eocene deposits of the Tertiary extend across the State in a northeast-southwest direction, forming a belt of varying width which is greatest around the region of Upper Marlboro, in Prince George's county. The Eocene is divisible into the following parts:[1]

Group.	Formation or stage.	Member or sub-stage.
Pamunkey	Nanjemoy	Woodstock.
		Potapaco.
	Aquia	Paspotansa.
		Piscataway.

These different members or sub-stages involve beds of sand, clayey sand, greensand, or marl, many of them fossiliferous, but only one of them contains clay deposits of any importance, viz.: the Potapaco.

This member is composed of greensand often very argillaceous, and at times gypseous, and a clayey member occurring in its lower portion. This clay, which is quite characteristic in appearance, is not found north of the South River, but extends from that point southwestward, showing a number of good outcrops, among which the fol-

[1] Report on the Eocene of Maryland, W. B. Clark and G. C. Martin.

lowing are especially prominent: In the valleys of the Western and the Charles branches of the Patuxent; on the road from Davidsonville to Annapolis, halfway between the former locality and South River; at Upper Marlboro; also at many points south of Hardesty. It also occurs on the west side of the Patuxent river in every little cove between Hardesty and Hills Bridge. The Marlboro clay is also fairly well exposed in the Potomac valley in Prince George's county, and even across the Potomac into Virginia.

The clay is a fine-grained red material with occasional streaks of sand, and, as exposed near Marlboro, is at least 20 feet thick, as shown in Plate XXIII, Fig. 2. Underlying the clay is a layer of sand about two feet in thickness. In places the sand grains have been cemented together into a ferruginous sandstone. The sample for testing was taken from the outcrop near the station of Marlboro on the Baltimore and Potomac Railroad, in Prince George's county (270, E. Washington 9).

The clay is fairly plastic, and no doubt would be suitable for pressed-brick and worthy of a trial for the manufacture of paving-brick. It is present in large quantity, and in close proximity to tidewater. This one point alone is of importance. It is not plastic enough for pottery, and rather too sandy for that purpose. Terra-cotta manufacturers could no doubt use it in their mixtures. It has a rather high shrinkage when burned to vitrification, but suitable means could be taken to dilute this.

Details of test are as follows: The clay passes entirely through a 100-mesh sieve, and about 20% of it remains on the 150-mesh sieve. On mixing it took 35% of water and gave a mass of fair plasticity. If too much water was added the clay became very sticky, anf if too little was put in the clay showed a tendency to crack in molding. Care had therefore to be taken to get just about the right amount. The average tensile strength of air-dried briquettes was 132 pounds per square inch, which is very fair. The air-shrinkage was 9%, which is somewhat large. At cone 05 incipient fusion began, with total shrinkage of 14% and color buff to red; at cone 1 the color was light red, and the shrinkage 15%; at cone 2, shrinkage 16% and color the same; at

cone 3, shrinkage 19%, brick nearly impervious, color red; at cone 6, vitrified, shrinkage 20%, color red. Viscous at cone 10.

The chemical composition of the clay is as follows:

ANALYSIS OF EOCENE CLAY FOUND NEAR MARLBORO STATION, PRINCE GEORGE'S COUNTY.

Silica	58.60
Alumina	28.71
Ferric oxide	3.22
Lime	.40
Magnesia	.35
Alkalies	.63
Ignition	8.90
Total	100.81
Total fluxes	4.60

The comparatively moderate silica percentage and high alumina account for its high shrinkage. The low lime and fair iron oxide contents insure a good red color to the brick. There are not enough fluxes to make it fuse at a very low temperature.

THE CRETACEOUS CLAYS.

Descriptive Geology of the Cretaceous Formations.

The deposits of Cretaceous and Jurassic age occupy large areas in Maryland and it is essential that the clay-worker should have some knowledge of the character and sequence of the beds in order that he may avoid the probably valueless beds and concentrate his attention on the more important deposits. The sequence of formations in the Cretaceous is as follows:

Upper Cretaceous	Rancocas.	
	Monmouth.	
	Matawan.	
Lower Cretaceous	Raritan.	Potomac group.
	Patapsco.	Potomac group.
Jurassic (?)	Arundel.	Potomac group.
	Patuxent.	Potomac group.

The Upper Cretaceous deposits of Maryland are a continuation of those of similar age occurring to the northeast in Delaware and New Jersey. They cross the State from northeast to southwest and are developed in Cecil, Kent, Arundel and Prince George's counties.

The full sequence of the New Jersey section is not present in

Maryland and the beds themselves have undergone certain changes and show a diminution of greensand and an increase of quartz sand. The Maryland section of the Upper Cretaceous, includes the Matawan and Monmouth formations. The presence of the Rancocas is extremely doubtful although it is found just across the State line in Delaware. These formations are composed largely of sand, loam and greensand but bear little clay; they are also overlain by deposits of Pleistocene materials which vary in thickness from 1 to 50 feet, or more. It is very doubtful if any of the material belonging to the Upper Cretaceous is of value as a workable clay. At the present time, at least, no pits have been opened in it for that purpose.

The Potomac group, on the other hand, is especially important to the clay-worker and the following general descriptions of the different formations may assist to a more complete understanding of the different portions of the group and their stratigraphic relations with one another.[1]

The Potomac group as a whole is composed of a series of sands, clays, sandy clays and gravels, which have been deposited at different periods, and under ever changing conditions, the result being that the most unlike materials may pass into each other horizontally, and beds of materials differing considerably in their coarseness may follow on top of one another.

The general dip of the beds is very slight, being from 30 to 50 feet per mile to the southeast.

From this it is not to be understood, however, that the different members of the Potomac group have well defined upper and lower limits, and an even top. On the contrary, the upper surface of any one member may be very uneven owing to the fact that it has been much eroded or worn down by water action, before the next member above it was deposited.

While therefore, if traced horizontally along the line of strike, any one member might be found at different levels, still the regularity of succession of the different members can be recognized if we follow across the surface at right angles to the line of strike, and

[1] In the preparation of this I have drawn freely on a paper by W. B. Clark and A. Bibbins. The Stratigraphy of the Potomac Group in Maryland, Journal of Geology, vol. v, 1897, pp. 479–506.

FIG. 1.—CLIFFS CONTAINING BEDS OF DIATOMACEOUS EARTH, LYONS WHARF, CALVERT COUNTY.

FIG. 2.—DIATOMACEOUS EARTH-PIT OF NEW YORK SILICITE COMPANY, LYONS WHARF, CALVERT COUNTY.

thereby encounter successively the outcrops from the lowest to the highest divisions.

RARITAN FORMATION.—This receives its name from its typical exposures along the Raritan river, N. J. The deposits of the Raritan consist of sands and clays, the former largely predominating in the upper portion of the formation, in other words in the eastern and southeastern portions of the belt in which it outcrops. The sands are often nearly white but at other times may be well colored by iron. The clays are usually light-colored, but in places may become variegated, red, very dark, or even black. The strike of the beds is similar to that of the other members of the Potomac group and their dip to the southeast is probably still less than that of the Patapsco, although it is hard to ascertain it with certainty. The thickness of the Raritan in central Maryland is estimated at not far from 200 feet, but it lessens in thickness greatly to the southward, disappearing near the District of Columbia. Perhaps the best sections of the Raritan occur on the west shore of Elk Neck at "Lower White Banks." The section is as follows:

SECTION OF RARITAN FORMATION AT "LOWER WHITE BANKS," WEST SHORE ELK NECK.

		Feet.
Pleistocene.	Gravelly loam	0–6
Raritan.	White sandy clay ("fuller's earth")	25
	Buff and brown cross-bedded sands, brightly iron tinted in the middle and lower portions, containing pebbles of white clay, indurated below	20
	Jointed light drab clay	2
	Fine dense drab plastic clay, laminated above and obscurely bedded below (conchoidal fracture), rich in exogenous leaf impressions	2
	Light drab and buff laminated clay with filmy partings of fine white sand	2
	Light-colored sands, locally consolidated	0–115
Patapsco.	Massive variegated and drab clays, mostly covered by talus, to tide	

This section however does not do justice to the importance of the Raritan member of the group as a clay-bearing formation, for there are many localities at which it contains clay of considerable thickness.

Patapsco Formation.—This derives its name from its typical occurrence on the shores of the Patapsco river, and extends entirely across the State from Delaware to the Potomac river and is a most important member of the Potomac group. In fact it has a much larger areal extent than either of the two formations described below. In places it may overlap both of them resting directly on the crystalline rocks of the Piedmont Plateau.

The Patapsco deposits consist chiefly of brightly-colored and mottled clays which sometimes grade into lighter colored sands and clays. In some cases they may be ore-bearing, but this is not nearly so often the case as in the Arundel. Again at times the clays in places are dark-colored and massive and more or less lignitic; at other times they are slaty with many leaf impressions, so that the Patapsco is capable of yielding a great variety of materials. The deposits of this member are not confined to clays but even grade over into cross-bedded sands, and at many points, usually near the base of the formation, are beds of highly ferruginous clays which are often firmly consolidated into "paint rock," or "red ocher."

The strike of the formation is practically the same as that of the Raritan, but the dip of the beds is somewhat less. A very marked unconformity is also found at many points between the Patapsco beds and the underlying ones, while in other places the boundary is obscure. The total thickness of the formation is estimated to be at least 200 feet.

The nature and thickness of the Patapsco can be seen in part by reference to the general sections which are given under the Patuxent and Arundel. Another section may however not be out of place, for it is an important one. This is a section from the locality known as Cedar Hill, in the area of Timberneck, in Howard county. The section is on Deep Run, one mile southwest of Hanover.

Section at Cedar Hill, Timberneck, Howard County.

		Feet.
Raritan.	Reddish sands, somewhat gravelly and indurated	12
Patapsco.	White, red, and brown sands, more or less argillaceous, containing clay pellets	20
Arundel.	Drab-colored pyritous clays with lignite and iron nodules	100
	White clay	5
Total thickness		137

Perhaps the most characteristic feature of the Patapsco formation is its variegated clay which occurs in enormous banks in many parts of the Coastal Plain region and is known locally as " terra cotta " clay.

ARUNDEL FORMATION.—This receives its name from its occurrence in Anne Arundel county where the deposits of this horizon are well developed. It has, like the Patapsco, been traced as a broken belt the entire distance from Cecil county to the District of Columbia, or more properly, it may be said to occur as a series of long, narrow belts that extend in a general N.W.-S.E. direction, forming a low angle with the border of the Piedmont Plateau.

The deposits form a series of great and small lenses or lenticular masses of iron-ore-bearing clays which have commonly been deposited in old depressions in the surface of the Patuxent formation. These clays which are sometimes spoken of by the miners as blue-charcoal clay are usually dark-colored and very tough; at times they are highly carbonaceous. Scattered through the clays there are often large quantities of iron carbonate nodules; and in the search for these ore nodules great beds of the clay are often dug over.

Those nodules which existed in the upper beds and have been exposed to atmospheric influences, however, sometimes change to the hydrous oxide of iron or limonite, the layers of clay in which they occur becoming similarly altered. This alteration of the clay has resulted in the production of red or variegated clays. It is highly probable that these Arundel clays may at some time in the future become of great importance, especially if some easy means is adopted for freeing them from the small lumps of iron ore which they often contain.

These lens-shaped deposits of the Arundel formation vary considerably in size and may range from a few feet up to a possible thickness of 125 feet.

One of the best Arundel sections is that found at Reynold's Mine, on Piney Run, Anne Arundel county, one mile south of Hanover. The section is as follows:

SECTION AT REYNOLD'S MINE, PINEY RUN, ANNE ARUNDEL COUNTY.

		Feet.
Raritan.	White and light brown sand, gravel containing crusts of iron stone	10
Patapsco.	White and variegated argillaceous sands ("fuller's earth"), etc., "paint rock" at base	10
Arundel.	Drab-colored, compact, laminated clays containing nodules of ore and also plant impressions	70 +
	Total thickness	90 +

Another good section is found at Muirkirk, Prince George's county, at a locality known as the Old Blue Bank, on the Tyson estate.

SECTION OF OLD BLUE BANK, MUIRKIRK, PRINCE GEORGE'S COUNTY.

		Feet.
Pleistocene.	Sandy gravel	4
Patapsco.	Mottled, gravelly loam	12
Arundel.	Massive blue clay	20
	Highly lignitic clay with "charcoal ore"	2
	Tough, dry, blue clay, with "white ore"	15
Patuxent.	White sand	10 +
	Total thickness	63 +

Other places where lenses of the Arundel clay have been noticed are, near Sewell, Harford county; in the vicinity of Joppa, Harford county; on Stemmer's Run, Baltimore county; at Locust Point, Baltimore city. An interesting paleontological character of these clays is that the plants consist of ferns, conifers and monocotyledons, while only a few dicotyledons occur. In the Raritan clays, on the contrary, dicotyledonous plants greatly predominate.

PATUXENT FORMATION.—This is so called from its occurrence in the basin of the Patuxent river. Since it is the basal member of the Potomac group the Patuxent formation is naturally found near the landward margin of the Coastal Plain, although the higher members of the series are sometimes found further inland, and even resting on the crystalline rocks of the Piedmont Plateau, because they have overlapped it during their deposition. The Patuxent formation can be traced as a narrow, irregular and sometimes broken belt from Cecil county on the northeast across Harford, Baltimore, Anne Arundel and Prince George's counties to the borders of the District of Columbia on the southwest.

The general character of the Patuxent deposits is that of a sand which at times is very highly silicious and free from iron, and yet often. on the other hand, containing a considerable number of grains of partially decomposed feldspar. Again, at times balls and pellets of clay are often found distributed through the sand layers and sometimes even coarser fragments such as cobble-stones. At some localities the sands grade into sandy clays, and these again may even pass into plastic clays which, while they are usually of a light color, may also show brown or red tints. The strike of the beds is in general N.N.E. and S.S.W. and the dip between 30 and 40 feet to the mile, according to Clark and Bibbins, but this measurement is rather difficult to make owing to the small area of outcrop of the deposits. The thickness of the Patuxent formation varies but is probably not over 150 feet at most localities.

Among the characteristic sections of the Patuxent formation is one in a cutting of the Baltimore and Ohio Railroad, a short distance to the south of Contee. Here the coarse, gravelly sands are well exposed and are overlain by the iron-ore clays of the Arundel formation which lies next above the Patuxent. A still better section and one showing the character of the Patuxent beds is the bed at School-house Hill, Baltimore county, about ¾ mile northwest of Lansdowne, on the Baltimore and Ohio Railroad. A magnificent section involving three members of the Potomac group is here shown. Beginning at the top it is as follows:

SECTION AT SCHOOL-HOUSE HILL, BALTIMORE COUNTY.

		Feet.
Patapsco.	Argillaceous sands, and variegated clays more or less iron-stained in places	10
Arundel.	An indurated, argillaceous ledge with many impressions of monocotyledonous plants	1
	Drab-colored clays with beds of lignite containing brown and white ore and showing impressions of various ferns and teeth	50
Patuxent.	Compact, yellowish, reddish, and variegated sands, locally carbonaceous; brown clays containing flakes of iron-ore, lead-colored clays; fragmentary plant remains	30
	Compact jointed clays of many colors; "paint rock" and lenses of coarse gravel containing balls of clay and silicified wood	20
	Cross-bedded, sandy, slightly carbonaceous clay	10
Total thickness		121

Still another section may be quoted which is of interest because the Patapsco formation is found lying directly on the Patuxent, although a short distance off the Arundel beds are found in their proper position, in between the two. This is a feature of some economic bearing for the reason that, owing to the absence of a particular member in one place it should not be taken for granted that it is also missing at other points close by, and that in prospecting for any particular type of clays an abundant and sufficient number of borings should be made before search is given up. The section referred to above is that near Federal Hill, Baltimore City.

SECTION AT FEDERAL HILL, BALTIMORE CITY.

		Feet.	Inches.
Patapsco.	Sand and ferruginous sandstone	5	
	Carbonaceous clays, with white ore	1	4
	Variegated clays with iron-stained crusts	34	6
	Blue clay with lignite	7	6
	Slaty clays with many plant remains	7	10
	"Paint rock"		6
Arundel.	Missing.		
Patuxent.	White sand	7	
	Coarse sand with clay balls	4	
	White clay	5	
	Indurated gravel	4	
Total thickness		76	8

Attention should be called to the five-foot bed of white clay in the Patuxent. This is not an uncommon occurrence in this member, and this white clay is often of considerable refractoriness. Furthermore it is at times very fine-grained and might be found well adapted for use in the manufacture of paper.

Special Description of the Clays of the Potomac Group.

Raritan Formation.

This overlies the Patapsco, and in places contains important beds of clay. It is found in Cecil and Kent counties and extends from this point southwestward, following the southeastern border of Harford and Baltimore counties, and broadening out in Anne Arundel county where it forms a large area along the Severn river.

Beyond the valley of the Patuxent the area of the outcrops is very much narrower.

The maximum thickness of the Raritan formation is about 500 feet, and while it consists mainly of sands and gravel, still, near the base of the section there are some important beds of clay which vary in color and may at times be highly silicious. The thickness of the formation is, moreover, somewhat variable. Thus at the mouth of the Sassafras river in Cecil county it is 109 feet according to Mr. Bibbins, while at the western end of the Chesapeake and Delaware Canal in Cecil county it is 60 feet in thickness.

The counties in which the Raritan clays are found are Cecil, Kent, Harford, Baltimore, Anne Arundel, Prince George's, Howard and Montgomery. In all of these counties, but more especially in those to the eastward, the so-called fuller's earth clay is often seen. Variegated and red clays are also common, and occasionally drab stoneware clays are likewise found in the Raritan beds. Perhaps the best development of this formation for clay-working is to be found along the Severn river and along Elk Neck.

At the base of the Raritan there is sometimes found a bed of red ocher, but its presence can not always be counted on.

Many of the darker colored Raritan clays contain leaf impressions, which in every case are strongly exogenous, with well-marked modern facies.

Cecil County.—The Raritan clays are found at scattered points in the county, but do not assume the importance which they do in Anne Arundel county. Where found, they usually form lenticular beds, sometimes well located, and not infrequently of a refractory nature. These latter are commonly white or yellowish-white in color, and somewhat silicious, bearing a general resemblance to the so-called fuller's earth found in the Patapsco formation. Among the more important exposures of Raritan clay in Cecil county the following may be mentioned:

A white, plastic, refractory clay (290, Elkton 7) is found at McKinneytown, 3 miles south-southeast of Northeast station. This clay, which has been excavated in the middle of a large field, is covered by at least three feet of grayish clay. Judging from the ex-

posures in neighboring gullies there is evidently a considerable deposit. This material has been excavated to a small extent and shipped to potteries. It is fairly refractory and burns to a whitish color, but not sufficiently white for the manufacture of chinaware. The air shrinkage is 5% and incipient fusion occurs slightly below cone 8, with a total shrinkage of 8%. At cone 27 in the Deville furnace it was just beginning to vitrify. For shipment it would have to be hauled about two and a half miles to the Northeast river.

This locality, 290, with 29, a short distance east represents one of the many lenticular beds of white Raritan clay to be found in this region.

About one mile northeast of Elk Neck Village, on Piney Creek, are beds of plastic blue and yellow clay seven to eight feet in thickness. At the base of the section the clay is quite lignitic (32, Elkton 7).

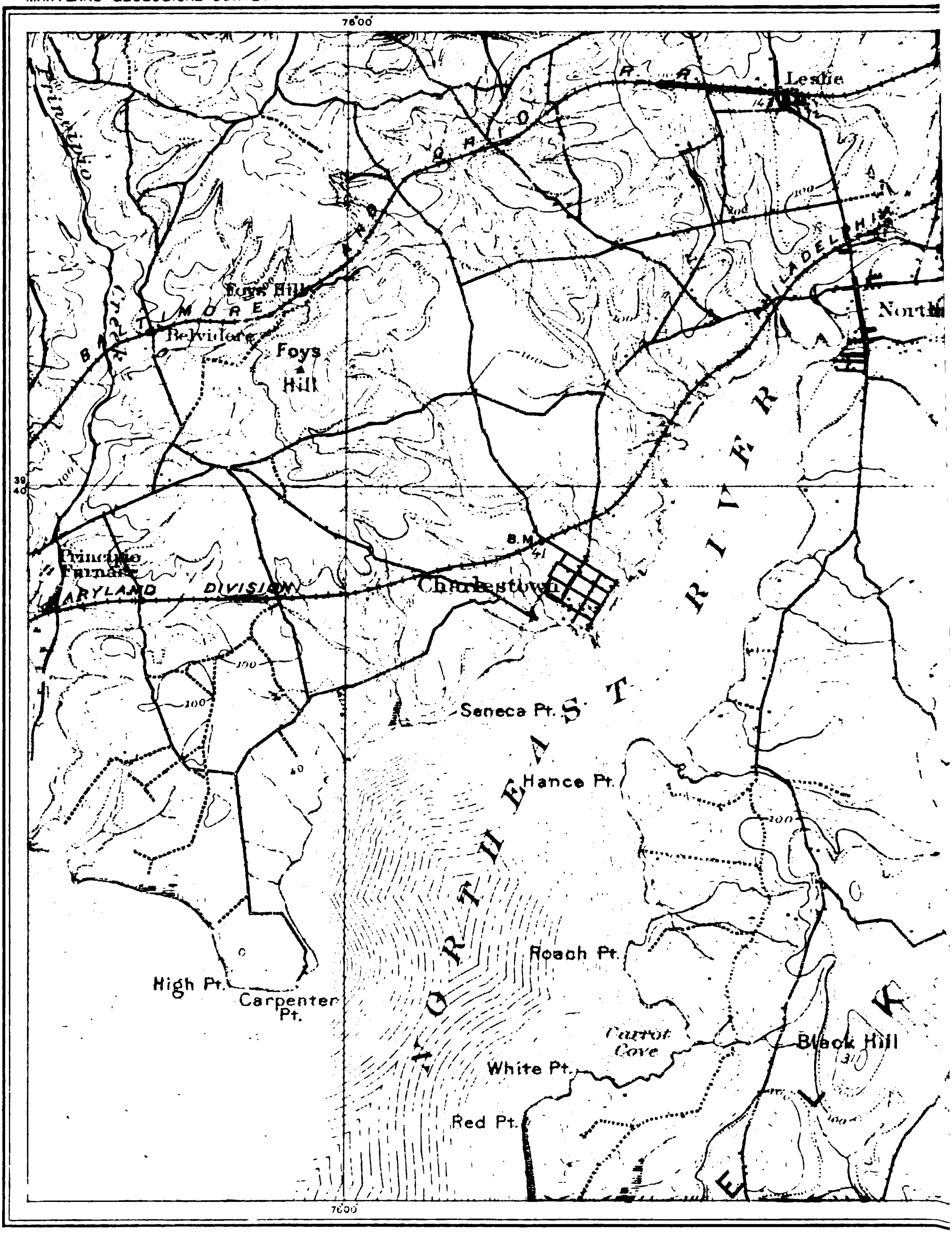
Going from here up the hill to the east of Piney Creek on the old road to Elkton there are numerous indications of white clay which are similar to that found on Ford's place (264, Elkton 4) on the edge of the town of Northeast. The latter outcrops are, however, at a much lower horizon for they are of Patuxent age.

At a point ½ mile north of Elk Neck (86, Elkton 7) are small series of Raritan clay beds, but none of the outcrops indicate exposures sufficiently large to be of any commercial value.

Along the eastern shore of Northeast river, northeast of Bull Mountain and due west from Elk Neck (30, Elkton 7) the outcrops show fifteen feet of chocolate and bluish-black plastic clay with much fine sand and also appreciable fine mica. It resembles somewhat sample 86.

One of the best exposures of white clay of Raritan age is to be seen at the White Banks, at the base of Maulden Mountain. Since the section also involves considerable Patapsco it is mentioned under that formation.

Another deposit of whitish clay occurs on the C. W. Purner estate on Elk Neck, where it is exposed in the north and south banks of the mill-dam at Piney Creek (8771, Elkton 7). Its character is semi-refractory.



Patuxent

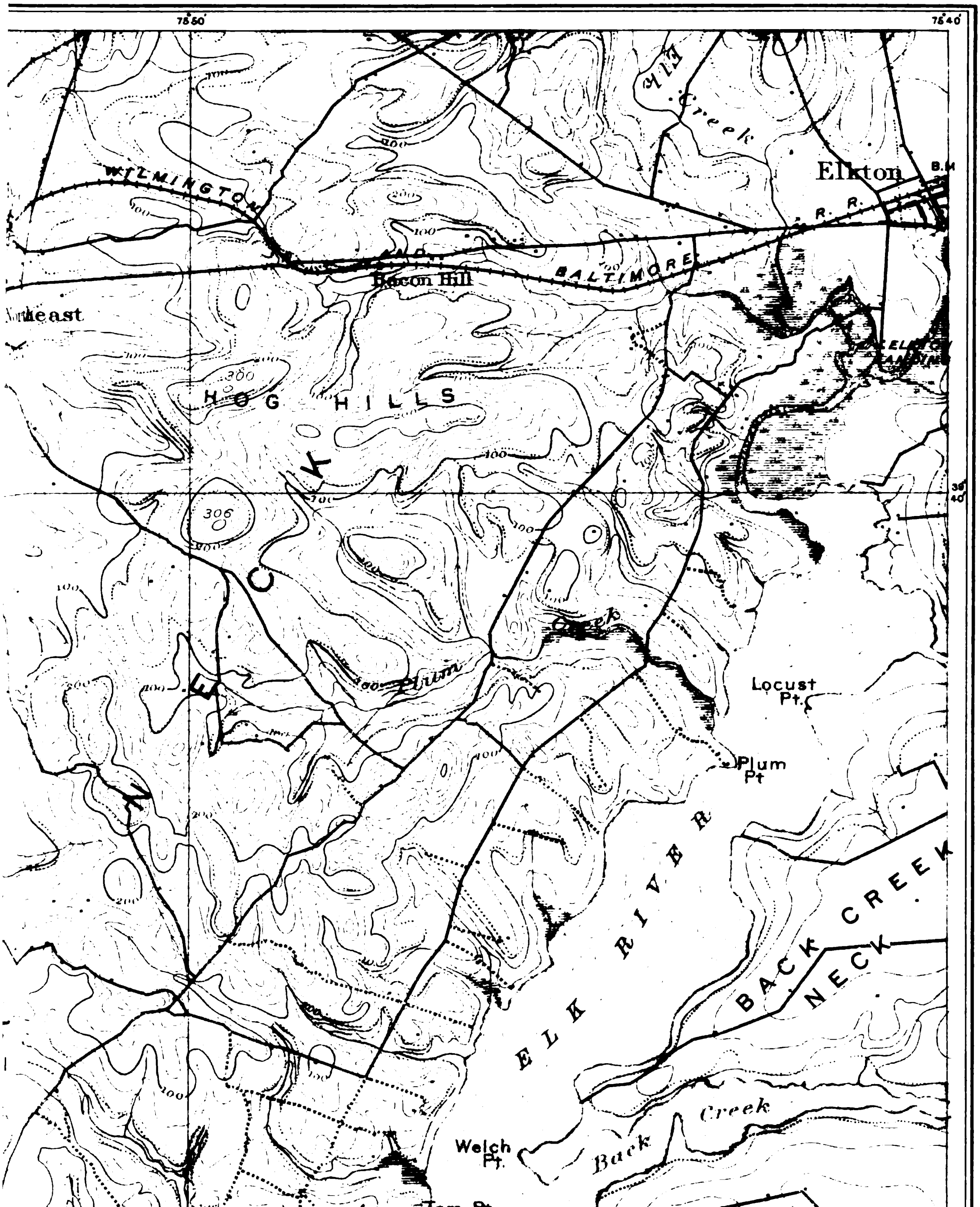
Pa

MAP OF CENTRAL

SHOWING AREAL DISTRIBUTION OF CLAY-BEAR

Scale

1902



Patapsco
Raritan

TRAL CECIL COUNTY
BEARING FORMATIONS OF THE POTOMAC GROUP

ale 1/62500
1 Mile

1902

White-burning clay outcrops in the Baltimore and Ohio Railroad cut at Foys Hill, Cecil county (5729, Havre de Grace 6).

A whitish, sandy clay of semi-refractory character is also found outcropping at Rogues Harbor, Cecil county. A fire test of the material showed it to be of refractory character (10, Cecilton 1).

Additional indications of white clay are found at a point 1½ miles northeast of Elkton (43, Elkton 6).

The Raritan clays outcrop near the base of the Raritan portion of the section at the Lower White Bank on Elk Neck (5795, Cecilton 1) where the thickness is known to be over 6 feet. The material is a light-colored, smooth, and rather plastic clay of semi-refractory character, becoming viscous at cone 27 in the Deville furnace.

Harford County.—The Raritan, though present in Harford county, is usually thickly covered by the Columbia loams. White clays of this age occur near Abingdon, and some blue clays along the Gunpowder river.

On the hill above Water's Mine one mile south of Clayton Station on the Baltimore and Ohio Railroad (9034, Gunpowder 3) there is an outcrop of rather gritty clay of low plasticity, which is, however, moderately refractory in its nature. A cone of it heated to the fusion point of cone 27 was thoroughly vitrified at this temperature, but had not become viscous. Its color was light yellowish-white.

Baltimore County.—Here, too, the Raritan is comparatively unimportant, forming only small patches capping the high hills eastward of Baltimore.

More sandy clay is found in Weaver's pit (259, Baltimore 8).

Anne Arundel County.—The Raritan clays reach their greatest development in this county. North of the Severn river there are exposures of a belt which extends across the middle of the Relay topographic sheet. They are usually at higher levels while the Patapsco clays are exposed in the streams, but some of the best exposures of Raritan clays to be found in the State, are those outcropping in the bluffs along the banks of the Severn river.

Of considerable importance are the beds of black clay (265, Relay 9) which outcrop on the property of William Jones in Swan Cove

on the Magothy river at a point about 5 miles from its mouth. The bank is fully 18 feet high and is underlain by a red and white variegated clay of Raritan age. The black clay belongs to the Magothy substage of the Raritan while the variegated belongs to the Albirupean substage. This is a very dark-colored, smooth-looking clay, rather stiff to dig and work, and containing much organic matter in a finely divided condition or as fossil leaves. There is very little grit in the clay, but tiny mica scales are rather common. It takes a rather high percentage of water to work it up, viz., 34.5%. This high absorption is no doubt partly due to the presence of the organic matter.

In general it can be said to be of very fair plasticity, burning to a red buff at moderate temperature, such as cone 4, but deepening in color if heated above this. It recommends itself to manufacturers of pressed brick and terra cotta, and perhaps also to paving-brick manufacturers, if mixed with some of the other clays of the region. Being along the river it is easily accessible for shipping.

The details of the tests are: air-shrinkage 8%; tensile strength from 120 to 160 pounds per square inch, with an average of 135 pounds. Leaves practically no residue on a 150-mesh sieve, and slakes slowly in water. It has to be heated very slowly to prevent cracking, owing to the density of the material and organic matter present. Color at cone 05, buff, and shrinkage 12%; incipient fusion at cone 01; at cone 4 total shrinkage 15%, color reddish buff, and not yet vitrified. It vitrifies at cone 7.

On the property of John Groot on Cape Sable one hundred feet from the preceding locality there are small outcrops of whitish clay along the shore, but their depth is not known to exceed two feet. There is also a bluish clay outcropping at this point and it is said that two barrels of it were sent to Jersey City to be used in the manufacture of crucibles.

In the cove between Proctor's Park and Cape Sable are several small bluffs showing exposures of whitish sand which would no doubt be suitable for the manufacture of glass. Aside from these outcrops mentioned in the preceding paragraph there are no very extensive outcrops along the Magothy river.

A dense, hard, light yellowish clay, known as "alum clay," having a strong acid taste, forms a bed about 2 feet thick at Cape Sable (6283, Relay 9). Its appearance would suggest that it might be refractory, but it is not at all so.

Along the Severn river the outcrops are much more abundant. Thus, directly across from Proctor's Park, there is more or less white clay outcropping. It is at least nine feet and the overburden consists of four to six feet of sand (51, Relay 9) and is moderately refractory.

Owing to the sandy nature of these clays the surface waters with limonite have often penetrated them to the depth of at least two feet so that the upper layers may be badly discolored. Some of these will, no doubt, be found similar to those from the Patuxent found at the new Courthouse site in the city of Baltimore.

The silicious clays are well seen again near the head of the Severn river in Captain Brown's glass-sand pits, where there is exposed a large section of sand and clay (246, Relay 9). In the southwestern face of the pit the section involves:

SECTION AT BROWN'S GLASS-SAND PITS, ANNE ARUNDEL COUNTY.

	Feet
Glass sand	20
Impure sand	15
Variegated clay	50

On the north end of the pit the glass-sand is overlain by 2 to 6 feet of reddish clay, and this by a bed of blue pottery clay which runs from a few inches to 8 feet in thickness, a few inches of soil capping the whole. A white clay also occurs in a small quantity in the bank between Captain Brown's pit and Spear's pit which joins it on the southeast.

The white clay from Captain Brown's glass-sand pit is a dense, white clay which slakes rather slowly. It is finer grained than the material found in the pits on the opposite side of the river and somewhat less refractory. Its characteristics are somewhat as follows: air-shrinkage, 6%; incipient fusion at cone 1 to 2, shrinkage 11%, color whitish; cone 5, color yellow, total shrinkage, 13%; vitrification, cone 10, shrinkage 16%, color grayish; viscosity at cone 27. Its tensile strength is low. The clay is thus seen to be moderately refractory.

The red clay found in Brown's glass-sand pits (247, Relay 9) is material of considerable plasticity and rapid-slaking quality but is not refractory in its nature. It has been used to some extent as a pottery clay, but would perhaps give better satisfaction in the manufacture of pressed brick. The air-shrinkage of the material is 5%, which increases to 7% at cone 03, and to 10% at cone 4, at which temperature it forms good hard product of light red color but is not vitrified. The point of vitrification in fact is rather high for the manufacture of structural wares, since it does not occur until cone 8. The total shrinkage up to this last point was 16%.

On the opposite side of the Severn river from Captain Brown's pits are the pits belonging to Mr. Baldwin (238, Relay 8). In these there is a 20-foot bed of whitish, sandy clay overlying the glass-sand which is not, in its general character, unlike the sandy clay that was obtained from the Patuxent formation while digging foundations for the Baltimore Courthouse. When freshly mined it is quite soft and breaks down easily. It is quite even-textured in grain and comparatively free from limonite stains. From the pyrometric tests which follow it will be seen that the clay is to be classed as a refractory one, for it does not vitrify until the fusing point of cone 28 is reached, as determined by a test made in Deville furnace. At the same time it burns sufficiently hard at cone 4 to resist scratching with the knife-blade, and at this point shows a total shrinkage of 7%. When burned to cone 10 the clay has a total shrinkage of 13% and is still slightly absorbent. Its average tensile strength is naturally low, being about 50 pounds per square inch.

Analysis of this clay gave:

ANALYSIS OF CLAY FROM BALDWIN'S PITS, ANNE ARUNDEL COUNTY.

Silica	75.40
Alumina	16.73
Ferric oxide	1.27
Lime	.35
Magnesia	.90
Alkalies	.50
Ignition	5.30
Total	100.45
Total fluxes	3.02

The high silica contents accounts for the low tensile strength, moderate shrinkage and sandiness. The total fluxes of only 3.02% point towards refractory character.

Underlying the brick clay at the Riverside Brickworks near the head of the Severn river there is a blue clay of great plasticity at least seven feet in thickness. The brick clay covering it is about 20 feet thick and of variegated color, while underlying it is a sandy clay. It was formerly worked at the brickworks which were located at this point (297, Relay 9). The material is known at that point as the "Bottom Blue clay."

No detailed test of this clay was made, there being simply a fire test in order to see how it compared with the upper clay in the same section, the result showing it to be a low grade of refractory material burning to a dense body at the temperature reached in terra cotta kilns and stoneware kilns. Its shrinkage when burnt to vitrification, as will be seen below, was rather high and would consequently have to be mixed with some less plastic material. At cone 03 the shrinkage was 9%, and the color of the clay was white. At cone 3 the clay became quite dense, with a total shrinkage of 14% and cream white color. The clay vitrifies at cone 10 with a total shrinkage of 17%, which is rather higher than would be desired in practice. It burns, however, to a very dense body.

White clay of a rather gritty nature occurs on the Dorsey estate near the line of the projected Drum Point railway (Dorsey, Relay 8). A sample of this material tested at cone 27 in the Deville furnace showed it to be fairly refractory. Some of this has been shipped to Washington. It is claimed also to have been used for modelling. It is not less than 6 feet thick and there is very little stripping.

According to Mr. P. B. Wilson, of Baltimore, this clay has the following composition:

ANALYSIS OF WHITE CLAY FROM DORSEY ESTATE, ANNE ARUNDEL COUNTY.

Silica	70.08
Alumina	23.00
Ferric oxide	.96
Water	5.96
	100.00

SECTION AT DORSEY ESTATE, ANNE ARUNDEL COUNTY.

	Feet.
Light-colored sand	10
White clay	4
White sand	1½
White clay	1
White sand	2½
White clay	depth unknown.

A bed of potter's clay occurs on the Dorsey estate at the head of the Severn river. Its thickness is at least five feet (8857, Relay 8).

A deposit of white, refractory clay of Raritan age is found on the Henry T. Wade estate, about 2½ miles south of Glenburnie (8843, Relay 5). It is a white, gritty, plastic clay and forms a bed about ten feet thick. The material is quite refractory, for, when heated to cone 27 the clay was not quite vitrified and the edges of the piece tested were still quite sharp. Another outcrop of practically the same material, as far as appearance goes, occurs just across the road from this locality, but is on the property of Geo. Warfield.

A good exposure of whitish Raritan clay occurs at a point about one mile south of Glenburnie and the material dug at this point has been used by Y. O. Wilson in the manufacture of buff brick. At this locality there are also blue beds of Raritan clay which are underlain by beds of gray clay of Patapsco age.

Clays for use in modelling have been found at Bodkin Point (North Point 4), Soper Hall (Relay 4), and Spring Gardens (Baltimore 8).

A large deposit of Raritan clay has been opened on the east side of the Pennsylvania Railroad about one-half mile south of Harman station (175, Relay 4). It is on the property of S. R. Shipley's heirs, and also on that of Wm. A. Ray, but that portion on the latter's property has not been opened up yet. The pit, which is about 10 feet deep, shows a gray-black gritty clay, overlain by four to eight feet of surface soil and sand, whose irregular under surface rests on paint-clay. The pit has been worked for three years by the Washington Hydraulic-Pressed Brick Company, and several carloads of the clay are shipped daily. It is claimed that the upper portion, which is

more weathered, burns buff, while the lower beds burn whitish or gray-white, depending on the nature of the burning.

The clay mixed with 19% water to a moderately plastic mass, which had an air-shrinkage of 4%, and a tensile strength when air-dried of 60 to 70 pounds per square inch. At cone 2 the clay burns cream white with a total shrinkage of 7%; at cone 8 it burns creamy-white, with a total shrinkage of 10%, and little absorption. While when burned to this temperature it cannot be scratched with a knife, still it is not vitrified. The clay is moderately refractory and affords an interesting comparison with that found at Horsepen Run.

Clay suitable for the manufacture of white bricks and refractory ware occurs on the Spear estate, Earleigh Heights (8851, Relay 8).

Another outcrop of this material occurs at locality (8852, Relay 8) on Earleigh Heights. The material from this point is very refractory for when heated to cone 27 the clay is barely vitrified.

Prince George's County.—An abundance of Raritan clay occurs on Horsepen Run. It is dark gray in color, and in appearance resembles that found south of Harman along the Pennsylvania Railroad. The bed, according to Mr. Bibbins, is 20 feet thick, and overlies mottled Patapsco clay. Its horizontal limits have not been accurately determined but there is evidently a considerable deposit: it grades laterally into sands. The clay shows good refractoriness, being only vitrified at cone 27, and is well worth investigation.

Kent County.—At Worton Point in Kent county (Betterton 7) there are variegated and blue clays of Raritan age which are approximately 20 feet thick and form a very extensive bed, the cliff in which they outcrop more or less continuously being about ¾ mile long. In places the clay is overlain by Pleistocene loessoid loam.

Patapsco Formation.

This formation, which underlies the Raritan, shows its best development in the valley of the Patapsco river. It is a most important member of the Cretaceous series and extends entirely across the State from the Delaware border to the Potomac river. Being a shallow-water formation it contains many beds of sand and indeed the clays themselves are often quite sandy.

At many localities the great beds of variegated red and white clay belonging to this formation form a conspicuous feature of the topography, and are known locally as "terra cotta" clay. In Cecil county there is often a bed of plastic bluish stoneware clay at the base of the formation underlying the variegated material. The total thickness of the formation is considered to be about 200 feet.

Cecil County.—STONEWARE CLAYS.—Near the base of the Patapsco and sometimes underlying the variegated clays of this formation there is often a deposit of bluish-gray, plastic clay, which in many cases is found suitable for the manufacture of stoneware.

A good example of this lower bluish-gray clay is seen on the property of Mr. Warren Grosh, on the Bacon Hill road about 3½ miles east of the town of Northeast (234, Elkton 5). The material is a blue, plastic clay, known to be from 7 to 10 feet thick. The deposit lies below the level of the wagon road. With it there occurs some yellowish clay forming about one-third of the whole mass which is dug and shipped with the blue material. The clay is sent to stoneware factories in Philadelphia.

The clay slakes rather slowly because it is so dense and plastic. A sample of it was accordingly submitted to a physical examination, the results to serve rather for comparative purposes than to determine the actual value of the material itself.

In tempering the clay 23% of water was required and the bricklets made from this had an air-shrinkage of 6%. The average tensile strength of the air-dried briquettes was 111 pounds per square inch and ranged from 110 to 125 pounds.

In burning incipient fusion occurred at cone 01, with a total shrinkage of 9%, the color of the burnt clay being cream white. At cone 02 the shrinkage was 10%, at cone 4, 11%; at cone 5, 15%. The clay was then nearly vitrified and this actually occurred at cone 8, with a total shrinkage of 16%.

The soluble salts in the clay are comparatively low, amounting to but one-tenth of one per cent; its chemical composition is:

FIG. 1.—PATAPSCO "FULLER'S EARTH" AT MULDEN MOUNTAIN.

FIG. 2.—PATAPSCO CLAY IN CUT EAST OF PRINCIPIO STATION, CECIL COUNTY.

ANALYSIS OF STONEWARE CLAY, BACON HILL, CECIL COUNTY.

Silica	65.70
Alumina	20.30
Ferric oxide	1.00
Lime	3.50
Magnesia	1.44
Alkalies	.62
Ignition	7.60
Total	100.16
Total fluxes	6.56

From the low percentage of iron which the clay shows and also on account of the excess of lime over iron we should expect it to burn yellowish or buff. The total percentage of fluxes (6.56%), is too high to allow of its being refractory. The silica percentage is not excessive.

An important clay deposit is found along the shore at the head of Beach channel, on the property of J. F. Simpcoe, near Carpenter Point (245, Havre de Grace 9). This is a bed fully 20 feet thick. Owing to its having been but little worked, the clay deposit does not show up prominently on the surface. A portion of the outcrop is shown in Plate LIII, Fig. 1.

The tests may be summarized by stating that it is probably a stoneware clay, but not a fire-clay. It could also be used in the manufacture of structural products where a buff color is desired.

Its properties are those of a very plastic, dense, slow-slaking clay requiring 33% of water to work it up. The air-shrinkage is 6%. It burns cream white up to cone 4, with a total shrinkage of 11%, but above this begins to redden. Incipient fusion begins slightly below cone 1, and vitrification near cone 8. At cone 01 the color is cream. It becomes viscous at cone 25 to 26, or in other words at about 2800 degrees Fahrenheit.

The clay when burned yields a good, hard body and should recommend itself to stoneware manufacturers. In fact, some of it was at one time shipped to Philadelphia for that purpose. The tensile strength of air-dried briquettes ranges from 110 to 125 pounds per square inch with an average of 115 pounds.

The chemical composition of this clay is:

ANALYSIS OF STONEWARE CLAY, CARPENTER POINT, CECIL COUNTY.

Silica	72.50
Alumina	17.00
Ferric oxide	1.50
Lime	.35
Magnesia	.60
Alkalies	1.10
Ignition	6.50
Total	99.55
Total fluxes	3.55

The total fluxes are not very high, but being chiefly ferric oxide and alkalies as shown by the analysis, lower the refractoriness of the clay.

On the property of Mr. Charles Simpress about one-half mile south of Eder, a clay deposit has been opened up in the field which shows three different types of clay (240, 288 and 292, Elkton 5). No. 240 is red, 288 white, and 292 chocolate. The first is found in the bottom of the pit and sent to Cowden's brick works at Northeast for the manufacture of stove-brick, the yellow and white going to R. Remey & Son of Philadelphia, for the manufacture of stoneware.

The white clay (288) which can be classed as a fire-clay, is a smooth clay of moderate plasticity and no further test was made on it than to determine its refractoriness, which is good, since at cone 27 it was not quite vitrified.

No. 292, the chocolate-colored one, which is also a refractory clay contains considerable organic matter which, however, passes off on burning. There are also numerous mica scales. The material took 33% of water in mixing it and the bricklets made from it had an air-shrinkage of 5%. The average tensile strength of the air-dried briquettes was 70 pounds per square inch. At cone 2 the clay burns cream-colored with a total shrinkage of 8%, and is sufficiently hard to resist scratching with a knife; at cone 8 the total shrinkage was 11%, and the color buff with a tinge of gray, the gray probably being due to slight reducing action in the fire. At this point the body was hard and quite dense. Thorough vitrification was not reached until cone 27. The clay is therefore one of very fair refractoriness, and

would no doubt find application as an ingredient of a stoneware or terra cotta mixture. It could also be used in the manufacture of refractory wares. The raw clay contained one-tenth of one per cent of soluble salts.

The red clay (240) is used for making stove-bricks at Cowden's factory at Northeast. It is a soft, laminated clay which, however, slakes comparatively slowly.

Its air-shrinkage is moderate, being 6%, but its tensile strength is low, ranging from 68 to 75 pounds per square inch.

In burning, the clay becomes moderately hard at cone 2, and incipient fusion is not reached until cone 4, at which point the total shrinkage was 10%, and the color of the clay cream white. When burned to cone 10 the total shrinkage was 14% and the bricklets appeared nearly vitrified. At cone 27 in the Deville furnace the clay had not yet become viscous but appeared still vitrified and is therefore to be looked upon as a material of good fire-resisting quality.

Another deposit of stoneware clay occurs along the highway from ½ to 1 mile west of Bacon Hill (20 and 21, Elkton 5). It is underlain by Patuxent water-bearing sand and gravel. A stoneware clay is also found near here on Caleb Grant's properties and has been shipped to potteries.

Upon the property of J. H. Ford, on the edge of the town of Northeast (264, Elkton 4), there is an outcrop of white clay along Ford's Run which in its natural condition is very plastic. On the opposite side of the creek a micaceous, sandy clay has been taken out and used at the local fire-brick works. The section at this point involves:

SECTION ON FORD'S RUN, NORTHEAST, CECIL COUNTY.

		Feet.
Columbia.	Gravelly loam	3–6
Patapsco.	Variegated clays	1–1½
Patuxent.	White clay	5–8
	White sand	depth unknown

While the exposure at this point is not very large, still it is similar to many of the same horizon which are exposed at other points and its character is therefore worthy of consideration. The very whiteness of the material points towards its refractory character, which was borne out by tests made on it.

The clay is fairly plastic and slakes slowly in water. At cone 5

it burns to a white color, and is moderately hard, having a total shrinkage of 7%. At cone 10 the clay becomes fairly dense, but begins to assume a yellowish tint and has a total shrinkage of 8%. It does not vitrify, however, until cone 30, and consequently is to be looked on as a clay of excellent refractoriness. So far as I am aware it has not yet been tried for the manufacture of fire-bricks, although it is easily accessible.

Still another outcrop of Patapsco clay occurs on Plum Creek (8873, Elkton 8).

Chocolate and blue, slightly lignitic stoneware clay occurs on the Thomas Reed estate 2¼ miles southwest of Elkton (36b, Elkton 8). The clay is 12 to 14 feet thick and overlain by 4 feet of Columbia gravelly loam, while underlying it is a deposit of water-bearing sand. No test was made of it, but its appearance is promising.

Another body of stoneware clay is found at the northern base of Bull Mountain on Elk Neck (88, Elkton 7). Here, however, the stripping is as much as 30 or 40 feet, which would make the working of the material rather unprofitable, unless some use could be found for the overburden.

At Wilson's Beach at the base of Maulden Mountain and southward along the shore from this point, there are a number of outcrops of Columbia clays and a rather large one of variegated Patapsco (92, Cecilton 1).

About ¾ mile south of Wilson's is a large bluff showing a variety of clays and sands, which are arranged in lenticular beds, the most unlike materials passing into each other horizontally. The samples collected were the so-called fuller's earth and blue potter's clay. The upper end of the bluff known as the "Upper White Banks" or upper end of the Maulden Mountain shows the following section:

SECTION AT UPPER WHITE BANKS, CECIL COUNTY.

		Feet
Pleistocene.	Brown conglomerate, and loam	10
Raritan.	Pink, white, yellow, bedded, sandy clay	20
	White clay more or less sandy known as fuller's earth and grading upward into blue	15–30
Patapsco.	Massive variegated clay	10

The blue clay also crops out on the land of Captain Fletcher Wilson, one-half mile below this point.

The Raritan and Patapsco clays are suited for brick manufacture, and the fuller's earth is semi-refractory in its character.

Another bed of blue potter's clay outcrops at the water-level, showing a thickness varying from 5 to 14 feet, and averaging 8 feet. It has been used by R. Remey and Son of Philadelphia for the manufacture of stoneware. Over this there are four feet of sandy, buff clay. The section exposed is:

SECTION SOUTH OF HANCE POINT, CECIL COUNTY.

	Feet
Variegated and white plastic clay	
Buff, sandy clay, (296)	4
Blue clay, average, (253)	8
Buff clay	2–3

The clay is well exposed on the bluff along the shore where the latter is high and Columbia clay is also involved in the section. This Columbia material has been used in the manufacture of flower pots, but it would not be suited for any better grades of pottery.

Blue fire-clay is found on Chas. Simpress' property, along the eastern shore of the Northeast river, and southeast of Charlestown, at a point halfway between Hance Point and Roach Point and just south of the termination of a private road (253, Elkton 7). This material has been shipped to some extent to R. Remey and Son of Philadelphia. It is a sandy clay containing mica scales, and slaking moderately fast. It requires about 30% of water to temper it and gave a mass of but moderate plasticity and not excessive tensile strength, the latter averaging about 40 pounds per square inch. The clay, however, has on the whole a low shrinkage in burning, good refractoriness, and burns to a creamy white color, thereby making it perhaps a desirable ingredient for some pottery mixtures. The air-shrinkage of the clay was 6%, while at cone 2 it amounted to 8½%. Incipient fusion was not reached until cone 8, with a total shrinkage of 10%, the brick still being very absorbent. At cone 27 in the Deville furnace the clay was not quite vitrified.

A buff fire-clay (29, Elkton 7), but one of lower refractoriness than the preceding, overlies it, forming a bed four feet thick as given in the section above. It burns to a whitish product at low temperatures and to a light buff at higher temperatures. The air-shrinkage

is 8%, at cone 2 it is 12%, and at cone 8, it is 14%. At the last temperature the clay is nearly vitrified, while at cone 2 it cannot be scratched with the knife.

More stoneware clay has been found at a point 3¼ miles due southwest of Elkton station (35, Elkton 8). The material has been used for the manufacture of stoneware and also of vitrified brick.

Still more material of similar nature is found along the shore, one mile northwest of Oldfield Point (37, Elkton 8.) A section here shows:

SECTION ONE MILE SOUTH OF OLDFIELD POINT, CECIL COUNTY.

		Feet.
Pleistocene.	Loam	3–6
Raritan.	Sands	6
Patapsco.	Massive, drab-colored, plastic clay containing some iron and lignite stains towards the top	8

This latter is used for the manufacture of stoneware.

Stoneware clay is also found along the road from Northeast to Elk Neck, at a point about ½ mile south of Northeast (18, Elkton 4). It is said to have been used in the manufacture of stoneware. At the time of the writer's visit the pit had been washed in and samples were not obtainable.

FIRE-CLAYS.—A white sandy clay of moderately refractory nature is found west of Bacon Hill (8775, Elkton 5). In general appearance it resembles the so-called fuller's earth found in many parts of this formation but is somewhat less sandy. Its thickness is about ten feet.

On the property of Henry L. Gaw, below Hance Point is a white, grayish clay cropping out along the shore, and, according to Mr. McDowell, running from seven to eight feet in thickness.

Black refractory clays are occasionally found in the Patapsco formation. Their color is due to lignite material, with which they are heavily charged. One of these beds of black clay outcrops at Broad Creek (256, Elkton 4), 1¾ miles due west of Northeast. The deposit is about 4 feet thick. The section shows:

SECTION ON BROAD CREEK, CECIL COUNTY.

		Feet
Pleistocene.	Sand	2
Patapsco.	Red clay	15
Patuxent.	Black fire-clay	4
	Quartzose conglomerate	2
Algonkian.	Kaolin	..

When examined the material is seen to be a dark, brownish-black clay, containing much mica and organic matter, but comparatively little iron, and having fair refractory quality. A few bricklets were made up to test its fire qualities and they gave a buff product, which at cone 6 showed a hardness of seven. The total shrinkage at cone 2 was 8%, and at cone 5, 12%, the color in both cases being buff. When heated to cone 27, the clay began to vitrify. It has been used to some extent in the manufacture of stove-linings and fire-bricks. The overburden at the Broad Creek locality would be some objection to its profitable working unless it can be utilized.

Another black, gritty, micaceous clay with much lignitic matter in it is found on the Neil property at Northeast (5796, Elkton 4). It is ground and used to some extent for paint. It is quite refractory, vitrifying at cone 27 in the Deville furnace.

An extensive bed of white fire-clay was struck in the digging of the well on the Clay Fall estate (52, Havre de Grace 9). Its exact thickness is not known, however.

At Grays Hill, Cecil county, there is known to be an extensive deposit of micaceous clay in the Patapsco formation (5817, Elkton 6). In fact, in the hand specimen the appearance is such as to make it appear a residual. A fire-test of this material showed in the Deville furnace at cone 27 that it is but vitrified at this temperature.

Associated with this same deposit of clay is another one which is far more micaceous in its character (5815, Elkton 6).

Brick and Terra Cotta Clay.—The Patapsco formation is not lacking in clays adapted for the manufacture of brick and terra cotta. The variegated Patapsco, often known as "terra cotta" clay, forms beds of vast extent at many localities, as will be mentioned below.

Several ten-foot beds of chocolate clay, separated by beds of sand, are exposed along the road leading to Elk Neck at Shannon Hill, which is about three and one-half miles south of Northeast (260, Elkton 7). The sample tested represents the average of a number of heavy beds which are exposed in the embankment along the highway. It is a clay of very fair plasticity, but contains much fine

grit. The degree of fineness can be estimated roughly by the fact that a 100-mesh sieve retained but 1.53%, while the 150-mesh sieve held a residue of 7.3%. Much of that which passed through was silt and there were also a number of tiny mica scales. The material required 20% of water to mix it, and the bricklets made from this had an air-shrinkage of 5%, while the average tensile strength of the air-dried briquettes was 100 pounds per square inch. At cone 05, which is about the temperature reached in some common brick kilns, the clay burns to a buff color, but can still be scratched with a knife. Incipient fusion occurred at cone 3, with a total shrinkage of 7%. At this temperature the material was reddish buff in color. At cone 5 the shrinkage was 7.5%, color red. The clay vitrifies at about cone 8.

On the Old Neck road about three miles south of Elkton and just north of Plum Creek (90, Elkton 8) are numerous exposures of Patapsco clays and sands suitable for brick manufacture. A section is somewhat as follows:

SECTION AT PLUM CREEK, CECIL COUNTY.

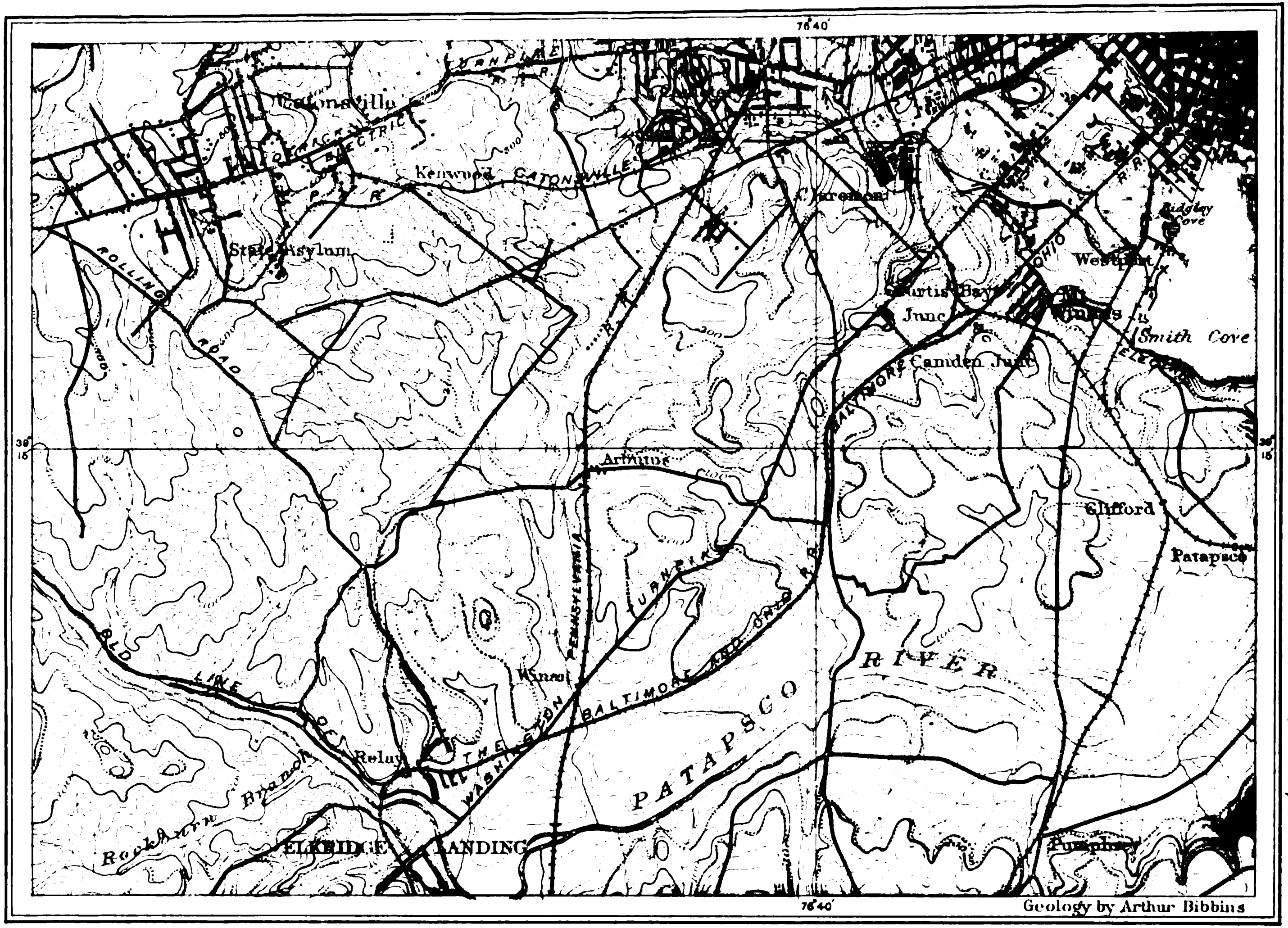
	Feet.
Loam	6
Light-colored sands and clays	8
Dark red and drab plastic clay with flakes of sandy iron carbonate.	8–12

Again in Thompson's gulley (91, Elkton 8) southwest of Elkton there is a large bed of Patapsco variegated clay, which is at least 20 feet thick and shows at the base of the section a bluish clay similar to those at locality 90, with less sand in it.

A sandy, micaceous brick clay of considerable thickness, locally known as "cowlick" clay was found outcropping on Locust Point, Cecil county (8828, Havre de Grace 9). Although the material appears refractory on inspection fire-tests show that it is not so, for at cone 27 it melts to a dark slag.

Exposures of Patapsco clays also occur along the shore from Carpenter Point northwest for a distance of ¾ of a mile.

Additional deposits of chocolate clay similar to (260, Elkton 7) occur at Hance Point (24, Elkton 7) and ¾ mile west of north from Elk Neck (85, Elkton 7).



Patuxent | Arundel | Patapsco | Raritan

MAP SHOWING AREAL DISTRIBUTION OF CLAY-BEARING FORMATIONS OF THE POTOMAC GROUP IN THE REGION SOUTHWEST OF BALTIMORE CITY

Scale $\frac{1}{62500}$

1 0 1 Mile

1902

A. HOEN & CO. BALTIMORE

Chocolate clays are known at other points in Cecil county but they are higher stratigraphically than 24 or 260.

Still another large deposit of Patapsco brick-clays is found near the east shore of Northeast river, 2½ miles south of Northeast (244, Elkton 7). They consist of the higher outcrops of red and blue clays, the latter being the lower in the section, which is as follows:

SECTION 2½ MILES SOUTH OF NORTHEAST, CECIL COUNTY.

	Feet
Stripping	5
Micaceous sandy clay	15
Dark gray plastic clay	8

At cone 8 this clay burns to a good dense stoneware body and is nearly vitrified, showing a total shrinkage of 12%.

A fine-grained, sandy clay of chocolate color is exposed northwest of Charlestown station on the Pennsylvania Railroad (16, Elkton 7). Its nature is such that it would probably be useful for stoneware, and there is, no doubt, a considerable bed of it, although the outcrop is not large.

Another large body occurs in the hill west of Charlestown (17, Elkton 7). There is a large amount of clay at this point and it would be an ideal site for a plant, as it is near the railroad and also near tide-water. There is also a thick bed of Patapsco clay overlying the black clay at Broad Creek (previously referred to). Under the Patapsco is a black lignitic clay (Patuxent) which is quite plastic. It is four to six feet thick. Under this comes a silicious breccia which overlies the kaolin.

Again there are large outcrops of the variegated Patapsco occurring in the river bluffs at Shadow Hall Point, 2 miles due south of Principio Furnace (50, Havre de Grace 9).

The variegated clays, as already mentioned, constitute an important element in the Patapsco formation. They are silicious, mottled red, white, pink, purple, etc. They are rather dense and often tough, and require more pugging than is usually given to them, in order to mix the red and white. Imperfect mixing produces a mottled product. When thoroughly tempered a red product results. In Cecil county one of the largest beds of variegated Patapsco occurs in the deep cut east of Principio station (255, Havre de Grace 9) on the

Pennsylvania Railroad. This is the ordinary variegated Patapsco of a red and white color. The clay at this point is at least 20 feet thick, and is overlain by 15 to 25 feet of merchantable sand. The outcrop is at least two hundred feet long (Plate XLVI, Fig. 2).

Great beds of Patapsco variegated clay are also seen on the hill ½ mile east of Red Point, near Elk Neck (84, Elkton 7). Small exposures occur at locality (85, Elkton 7) along the main road ¾ mile north of Elk Neck. There are also good exposures of the variegated material at the north end of Bald Mountain, locality (88, Elkton 7).

On the road from Elkton to Eder, about half-way between the two points, and just before reaching the branch road to Childs is another outcrop of variegated Patapsco (10, Elkton 5). It is stated that this has been used to some extent as a filler in the manufacture of pasteboard.

An extensive deposit of variegated Patapsco is found in the cut of the abandoned New Castle and Frenchtown Railroad (40, Elkton 9), three miles south of Elkton.

There are on Welch Point (34, Elkton 8) two beds of clay, namely an upper red, and a lower blue, the latter being mostly below tide-level. A plant was erected for grinding, cleaning and drying this clay for shipment, but it is now idle.

A vast deposit of Patapsco variegated and drab clays is exposed along the Philadelphia turnpike at Grays Hill, and a deposit of variegated Patapsco (43, Elkton 6) occurs about 1¾ miles north of this point. It is a very extensive deposit and is well exposed in the new cut of the Philadelphia, Wilmington and Baltimore Railroad, apparently an excellent location for an extensive clay-working concern.

Variegated Patapsco also outcrops in Foys cut on the Baltimore and Ohio Railroad (15, Havre de Grace 6). At this point there is, however, much overburden.

The Patapsco clays are also exposed at a point one and a half miles due west of Northeast station (13, Elkton 4); three-fourths of a mile due east of Elk Neck (31, Elkton 7), and along the shore of Northeast river, three-fourths of a mile south of Hance Point (25, Elkton 7).

Inexhaustible beds of variegated Patapsco clays occur in the immediate vicinity of Bacon Hill station on the Philadelphia, Wilmington and Baltimore Railroad, apparently a most favorable location for an extensive clay-working establishment.

Harford County.—The Patapsco clays are not lacking here, and the outcrops are mostly of the variegated variety. They are often covered by Columbia loams.

A bed of white, sandy fire-clay of good refractoriness is found above the public landing above Swan Creek (176, Betterton 2). There is not a great exposure, and the overburden is considerable.

Below the landing (177, Betterton 2) there is a creamy-colored and yellow clay at the same horizon, having a thickness of 5 feet. It is rather gritty and contains numerous tiny mica scales. It is less refractory than the preceding, becoming viscous at cone 27 in the Deville furnace.

There are also a number of clay outcrops of Patapsco age around the head of Bush River, especially on the eastern shore where there is a bed of variegated clay, associated with a bed of grayish sandy clay, 10 feet thick and covered by 10 feet of overburden. It is quite refractory, showing only incipient fusion at cone 27. The section at the mouth of Church Creek, according to Mr. Bibbins, is:

Section at Church Creek, Harford County.

		Feet
Pleistocene.	Loam and gravel	3–6
Patapsco.	Purple and red sandy clay	3
	White clay and fine white micaceous sand	15
	Concealed, apparently variegated clays	15

More Patapsco clay outcrops on Gunpowder river above the north end of the Philadelphia, Wilmington and Baltimore Railroad bridge (178, Gunpowder 5). It is here a laminated white clay, 10 feet thick, and overlain by 3 to 10 feet of Pleistocene. It is moderately refractory, becoming viscous at cone 27. Associated with it are several other beds of Patapsco clay of less refractory character, some of the latter being drab-colored and sandy.

A deposit of very sandy drab and white clays, suitable probably for brick or terra cotta, outcrops north of Otter Point Creek on the Buena Vista farm (Gunpowder 3). The variegated clays are well exposed on Maxwell Point (Gunpowder 6).

An extensive bed of variegated and other Patapsco clays constitutes the hill between Stepny P. O. and Cranberry Run, being well exposed along the public road. They are apparently suited to either brick or terra cotta and convenient to transportation either by rail or tide-water (Betterton 1).

Baltimore County.—In this county the Patapsco is found extensively developed in a triangular area between Bird river, the Philadelphia, Wilmington and Baltimore, and the Baltimore and Ohio railroads. A second area lies southwest of Rossville, and a third one, having a diameter of about 1½ miles, south of Bayview Junction.

At many points in the Patapsco there are lenticular masses of a white, sandy clay, which are known as fuller's earth. These have been referred to in Cecil county, and are also found in Baltimore county. A good example is found on the Edward Savage property, near the intersection of the high road at a point about 1¼ miles southeast of Mt. Winans, and ¼ mile inland from the shore followed by the electric road (254, Baltimore 8). This material is not a fuller's earth, although frequently so called, but is really a moderately refractory clay of sandy nature which burns to a creamy-white color. A partial test only was made of it in order to determine its fire-resisting qualities. The air-shrinkage is 4%, at cone 10 it is 5% and shows incipient fusion; at cone 27 in the Deville furnace the material is thoroughly vitrified. There is not enough exposed at this locality, or indeed at others where a similar clay is found, to make it worth mining as a fire-clay, but to those seeking a clay of this nature either on account of its refractoriness, color in burning, or for coating terra cotta, a knowledge of its properties and location may be useful. The clay is underlain by quartz sand.

A whitish, sandy clay of Patapsco age is found at Knecht's Brick works, Columbia Avenue, Baltimore (8816, Baltimore 8). Its color led to the testing of its refractoriness which was found to be considerable as at cone 27 the material had only vitrified.

Since the variegated Patapsco is so abundant it was deemed advisable to make a test of it although the Arundel clays are more commonly used for brick manufacture in this region. The sample tested

came from the clay bank of Major N. M. Rittenhouse, Jackson and Clement streets, Baltimore (32, Baltimore 8).

The material is a fine-grained, ferruginous clay which falls to pieces at once in water, and when mixed up yields a mass of very good plasticity, but requiring 31% of water for its working. The average tensile strength of the air-dried briquettes made from this material was 111 pounds per square inch, the air-shrinkage however, was large, being 9%, the fire-shrinkage was also rather great, thus at cone 01, the total shrinkage is 16%; at cone 1, 17%; at cone 4, 20%. Incipient fusion occurs at 05 and vitrification at cone 4, while the material burns to a deep red color of rather pleasing appearance.

In its natural condition the clay, instead of being of a red color throughout, is usually mottled, red and white, and it requires rather fine grinding and thorough mixing to blend these two colors and prevent speckling of the brick or the appearance of blotchy markings on the surface. This blotching is admirably developed by some of the stiff-mud machines. The high shrinkage of the clay is probably one reason which has interfered with its being used alone. This, however, could be counteracted by mixing in a sand.

Red brick clay of this age is found at Cromwell Bros. brick yard at Rossville (8952, Gunpowder 4). It is mixed with red loam.

Anne Arundel County.—The Patapsco clays belong mostly to the variegated variety, although a few deposits of refractory clay are found.

A body of white clay with limonite stains of Patapsco age is found near Walnut Point on Curtis Creek (8836, Relay 3). In general appearance it resembles somewhat the white sandy clays stained with limonite which are found on Bodkin Point. The material is probably semi-refractory.

Another deposit of Patapsco clay suitable for the manufacturer of smoking-pipes is being mined at a point about ½ mile south of Wellham station on the Baltimore and Annapolis Short Line (10, Relay 2). It is shipped to Baltimore for use. A fine-grained, plastic material which will not warp or crack in burning is required.

One deposit of very white clay of Patapsco age is found on the

property of J. C. Knecht, Stone House Cove, Baltimore county (5780, Relay 3).

Prince George's County.—The Patapsco begins at Hick's Mill with a width, from northwest to southeast, of 4 miles, and extends in a southwesterly direction with slightly decreasing width to Tuxedo, where it begins to narrow rapidly, and extends as a narrow belt through the District of Columbia to Anacostia.

It does not occur much below 80 feet above sea-level, and over much of this area extends to the hill tops, except where it is covered with a slight veneer of Columbia.

The clays in general are red or variegated, and no good stoneware clays are found, but to the southeast of Bowie there is, according to Mr. Bibbins, a considerable bed of drab clay, which contains nodules of iron carbonate. Another extensive bed of dense, light, mottled Patapsco clay some 25 feet thick occurs at Horsepen Run. This bed grades up stream into the drab, iron-bearing clays southeast of Bowie, above mentioned. An electric railway is to be constructed along the line of outcrop.

The variegated Patapsco clays are extensively exposed along the public road at the Broad Creek hill south of New Glatz. Their thickness at this point reaches more than 60 feet.

Patapsco variegated clays with considerable overburden are exposed in the deep Philadelphia, Wilmington and Baltimore Railroad cut 1 mile northeast of Bowie.

Yellowish clay, of rather fine texture, outcrops on the Bewley Bros. estate at Branchville (5851, Laurel 7). Its refractoriness is low, for in the Deville furnace at cone 27 it slagged. According to Mr. Bibbins, its thickness is about ten feet. On the other hand, a bluish-gray sandy clay of the same age which also occurs on this same property (5853, Laurel 7) is rather refractory, not beginning to show signs of viscosity until heated to cone 27. There is, furthermore, a bed of yellowish Patapsco clay, of refractory character, which at cone 27 is only vitrified (5857, Laurel 7). Reddish variegated Patapsco also occurs on the Bewley Bros. estate, Branchville (5856, Laurel 7).

A deposit of clay of apparently considerable thickness occurs on the

Stafford estate 3 miles east of Riverdale (8255, East Washington 2). The material is used for the manufacture of tiles and red paint.

Terra cotta clay outcrops on the Waverly estate 1 mile east of the College Station road cut in Prince George's county (5834, East Washington 2). The clay is of a variegated variety of the Patapsco found at many other points on the Coastal Plain.

Arundel Formation.

This has been so named on account of its great development in Anne Arundel county, where the formation shows a great series of lenticular clay deposits which often carry concretions of iron ore. These clays occupy ancient depressions in the surface of the Patuxent formation and are known all the way from Cecil county to the District of Columbia. In the search for the iron ore the surrounding clay is thrown to one side and accumulates in great heaps which in size rival the culm banks of the anthracite region of Pennsylvania.

The clays are often highly carbonaceous and lignitized tree trunks are sometimes found in them.

The Arundel clays are mostly blue, somewhat siliceous and of good plasticity. They are used in large quantities for the manufacture of common and pressed brick, terra cotta, roofing tile and common pottery. In some places these clays carry much less ore than in others, and it is preferable to use these. Where large deposits of Arundel clay occur, their greatest length is likely to be in a northwest southeast direction. If the clay is not free from iron concretions it may be necessary to put it through rolls to separate them.

Cecil County.—The Arundel clays of this county are limited to an area west of Charlestown. They are apparently unimportant from an economic point of view, owing to their small extent.

Harford County.—The Arundel clays are found near the surface in a strip lying southeast of the Baltimore and Ohio Railroad, but they are rather irregular in area of outcrop and are seldom free from a slight mantle of Columbia loam or clay. They, in nearly every instance, contain nodules of iron ore. One great bed of ore clay, some 30 feet thick, occurs at Prospect Hill, north of Joppa near the

head of Bird River. Other ore banks are found south of Joppa, near Clayton station and near the head of Otter Point Creek (151, 152, Gunpowder 3), east of Abingdon and west of Belcamp.

Arundel stoneware clay is dug on the south shore of Otter Point Creek opposite Light's landing (150, Gunpowder 3). It is shipped to New Jersey.

Potter's clay is also found south of Joppa, Harford county, at the John Everitt Iron Mine (5777, Gunpowder 2). There is a great abundance of this material which, although gritty, is very plastic. It also contains limonite stains and small fragments of lignite. It is probably not a fire-clay. A gritty plastic earthenware clay is known near the Light Mine, Joppa.

Baltimore County.—SEWER PIPE CLAYS.—Two types of Arundel clay are seen in the pits of Major N. M. Rittenhouse, Jackson and Clement streets, Baltimore. The upper is massive and the lower is "slaty."

The upper or normal type of Arundel clay from this station is the more plastic of the two, and requires 30% of water in tempering. From a commercial standpoint it is comparatively fine-grained because it leaves a residue of only 3% on a 150-mesh sieve. In burning it also forms a dense body at a moderate temperature as seen by the results given below. Neither is its shrinkage excessive, although a lower diminution in volume would be more desirable. The tensile strength is also good, being on the average 134 pounds per square inch. The material is not to be classed as a fire-clay, however, but rather as suited to the manufacture of wares requiring a vitrified body, such as sewer-pipe or paving-brick.

The results of the fire-test are as follows:

Air-shrinkage, 7%. Incipient fusion occurred at cone 1 with 11% total shrinkage, and color buff. At cone 3 the total shrinkage was 12½%, the color buff, but clay not vitrified. At cone 6, the shrinkage was 15%, the clay vitrified, and the color grayish-brown. At cone 8 viscosity had not showed any signs of appearing.

The composition of the clay is:

FIG. 1.—BANK OF BLUE ARUNDEL CLAY, NORTH OF CURTIS BAY JUNCTION, BALTIMORE COUNTY.

FIG. 2.—BANK SHOWING BLUE ARUNDEL CLAY ABOVE AND VARIEGATED ARUNDEL CLAY BELOW.

ANALYSIS OF SEWER-PIPE CLAY, BALTIMORE.

Silica	59.70
Alumina	27.00
Ferric oxide	2.10
Lime	.60
Magnesia	.52
Alkalies	1.96
Ignition	8.20
Total	100.08
Total fluxes	5.18

This analysis shows too high a percentage of fluxes for a fire-clay, but enough iron to burn red. The silica is not sufficiently high to indicate a very sandy clay. It is interesting to compare this type of Arundel clay with that found north of Curtis Bay Junction (250, Baltimore 8) described below. The higher percentage of alumina and fluxes accounts readily for its greater shrinkage and lower fusibility.

POTTER'S CLAY.—At times the Arundel clays show considerable freedom from silt, and are sufficiently fine-grained to permit their use for pottery manufacture. A deposit of potter's clay, 10 to 20 feet thick is being worked on the Ned Savage estate, Spring Gardens, Baltimore county (8877, Baltimore 8). The material has been used from time to time by the Edwin Bennett Pottery Company, at Baltimore. Mr. Bennett considers that many of the Arundel clays are well adapted to the manufacture of yellow ware.

FIRE-CLAY.—A semi-refractory blue clay is found at Locust Point (232, Baltimore 8) near Fort McHenry.

This clay is one of those which is used at the Baltimore Retort and Fire-brick works for the manufacture of fire-bricks and gas-retorts, and is used on account of its holding or bonding qualities, refractoriness and moderate shrinkage. It is a clay of somewhat sandy nature which slakes rather easily and mixes up to fairly plastic consistency. The air-shrinkage of the material was 5%. The average tensile strength of the air-dried briquettes was 65 pounds per square inch, with a maximum of 70. When burned to cone 1 the total shrinkage was 7%, and while the material had a hardness of more than six it was at the same time quite absorbent. At cone 5 the shrinkage was prac-

tically the same but it had increased to 9% at cone 8. Vitrification took place between cones 10 and 12, and the clay became viscous somewhat below cone 27. It burned to a cream color.

From these properties it will be seen that it is a semi-refractory clay, and one that evidently can be used in the making of refractory mixtures provided that it is not added in too large quantities.

Brick-clay.—One of the best exposures of Arundel clay near Baltimore is on a slope ½ mile north of Curtis Bay Junction and near the Washington road (Plate XLVIII, Fig. 1).

At this point there is a large bank showing fully 40 feet of Arundel clay, the upper being a dark-colored, micaceous, gritty material of considerable plasticity while the basal portion of ten feet thickness is variegated red and white. To the west and closely joining is a bank of whitish sand, with yellowish-brown streaks, probably of Patuxent age. This material seems to dip under the clay, the deposit just mentioned being more or less basin-shaped. This clay is dug to some extent for the manufacture of common brick and pressed brick at the neighboring yards of the Baltimore Brick Company.

The upper or blue clay (250, Baltimore 8) burns cream white at a moderate temperature, and softens slowly under the action of heat. I do not doubt that it would work well for face brick, but would not predict definitely the possibility of using it for making paving-brick. It is not a pottery clay nor a fire-clay, but could be used for terra cotta, as its total shrinkage is not great.

The clay is moderately fine-grained and leaves but 2½% residue on a 150-mesh sieve. There is considerable grit finer than 150 mesh in it however, and in water the clay slakes rather fast. It took 26½% of water to work it up. The air-dried bricklets from this mixture had a tensile strength of 73 pounds per square inch. The air-shrinkage of bricklets was 5%. Incipient fusion occurred at cone 2, with a total shrinkage of 10%, color light buff; at cone 6, the bricklet was nearly impervious, with a total shrinkage of 12%; vitrification occurred at cone 8, the color being yellowish-red.

The clay when wet is very plastic and sticky, and is evidently an example of one which does not show direct relation between the tensile strength and plasticity, as the majority of clays seem to.

The chemical composition of this clay is:

ANALYSIS OF BRICK-CLAY, CURTIS BAY JUNCTION, BALTIMORE COUNTY.

Silica	71.55
Alumina	17.70
Ferric oxide	2.25
Lime	.60
Magnesia	.86
Alkalies	.42
Ignition	6.50
Total	99.88
Total fluxes	4.13

The lower Arundel bed of this station, which is variegated (Plate XLVIII, Fig. 2), was also tested.

It is a fine-grained clay with very little grit and of red and white mottling. It is highly plastic and sticky, and takes 28% of water to mix up. The air-shrinkage of such a mixture is 7%. When burned it will not stand quick heating for then it cracks. In order to give a product of homogeneous color it has to be mixed up very thoroughly. Its tensile strength in the air-dried condition varies from 126 to 142 pounds per square inch. The slow slaking of it when thrown into water is some indication of the fact that the red and the white portions do not mix very readily without sufficient tempering.

In burning the following results were obtained:

It showed incipient fusion at cone 03. At cone 01 it burned brownish-red and showed a total shrinkage of 11%. At cone 6 it vitrified with a total shrinkage of 13%, color red. At cone 8, the total shrinkage was the same, and at cone 10 it became viscous or ran.

It works well in the manufacture of common bricks by the soft mud process, but for paving bricks it would need mixing with some clay of slightly less plasticity to give the best results.

Among the other exposures of the variegated Arundel clays is one at the yard of Smith & Swartz, of Baltimore (8950, Baltimore 8). This locality also contains blue clay (8954, Baltimore 8).

On the point to the southeast of Smith Cove (10, Baltimore 8) there is an old iron mine which contains an abundance of Arundel clay.

The material is of a dark, gray color, very plastic, and apparently moderately free from grit. There is probably not less than 20 feet of it which is overlain by 5 to 8 feet of Pleistocene material. Along the shore north of this there are a number of outcrops of Arundel clay in the embankment bordering on the electric railroad, but none of it seems equal in quality as far as freedom from grit and discoloration are concerned, to that just mentioned. A deposit more nearly resembling 8954 is found to the westward at locality (8955, Baltimore 8). Here there are a series of outcrops close to the shore but they have not been worked.

Great banks of Arundel material also occur at the Monumental Cement Works south of Baltimore, where they have been used for the manufacture of Portland cement (Plate XLIX, Fig. 1). Most of the clay is bluish-gray, although the upper portions are often oxidized to red or yellow. There are also some dark organic facies in parts of the bank. The material, of which there is a very large supply, has heretofore been used only for cement manufacture.

At a point one mile south of Mt. Winans (57, Baltimore 8) there are some extensive deposits of clay at Busey's brick-yard (Plate L). The deposit represents the dump of an old iron mine and contains two types of materials, namely thick beds of Arundel clay resting on beds of Patuxent material. The ore-bearing clay is in places as much as 40 feet thick but it often contains considerable quantities of stone. Both are used for making common brick.

A great development of the Arundel is also seen at Schwarz and Schwab's brick-yard in Baltimore, and around it there are a number of other outcrops of the same kind of clay.

Owing to the large amount of lignitic matter which the Arundel clay at times contains it is sometimes spoken of as "blue charcoal clay." A deposit of this type occurred at Classen's brick-yard in Baltimore (8958, Baltimore 8).

Another deposit of the so-called blue charcoal clay is found near the Washington road, in the clay pits of Pitcher and Creager, in the city of Baltimore (8321, Baltimore 8).

Terra Cotta Clay.—Clay for the manufacture of terra cotta is obtained from the pit of F. Link, near the junction of the Washington

FIG. 1.—VARIEGATED ARUNDEL CLAY, HERTEL'S BRICK YARD, BALTIMORE.

FIG. 2.—BANK OF ARUNDEL CLAY AT MONUMENTAL, BALTIMORE COUNTY.

turnpike and the Sulphur Springs road (257, Relay 1). (Plate LI, Fig. 2.) This clay lies in the Arundel formation, with a layer of red ocher and paint rock at the base. There are at least 15 feet of this clay exposed and it is overlain by very little stripping. The clay brings about $1.25 per ton delivered. The Arundel clays as shown in the case of Link's deposits are often more or less lenticular in shape and this is easily noticeable if an endeavor is made to trace these deposits for any great distance in different directions.

The special use of this material is the manufacture of terra cotta and it is much used by the Burns and Russell Company, but it could also be used in the manufacture of pressed brick. It is not a fire-clay, nor sufficiently plastic for a pottery clay.

It is very plastic to the feel, and has comparatively little coarse grit, leaving less than one per cent residue on a 150-mesh sieve. It slakes moderately fast, and takes 22½% of water to work up. The tensile strength of air-dried briquettes is 77 pounds per square inch, and the air-shrinkage of the clay 6%. In burning, the total shrinkage to cone 05 was 9%, and the color cream white; at cone 1 incipient fusion occurred, and the total shrinkage was 10%; at cone 2, 11%, and the color cream; at cone 3, 12%; at cone 6, the clay vitrified, and burned buff, with a total shrinkage of 15%.

The chemical composition of this clay is:

Analysis of Terra Cotta Clay, F. Link's Pit, Baltimore County.

Silica	68.30
Alumina	21.27
Ferric oxide	1.43
Lime	.52
Magnesia	.80
Alkalies	.20
Water	7.55
Total	100.07
Total fluxes	2.95

The low percentage of ferric oxide accounts for the buff color to which the clay burns.

Paint Clay.—Paint clay and paint rock occur at E. Link's pit, near the junction of the Washington turnpike and the Sulphur

Springs road (231, Relay 1). This clay forms a layer about one foot thick and lies at the base of the Arundel. Owing to its brilliant red color and comparative freedom from coarse sand grains it is much prized as a mineral paint ("Venetian red"). There is not sufficient of it to use for brick manufacture, and in fact it has more value for the use previously mentioned; but if sufficiently fine-grained and of proper composition, it could perhaps be used by pottery manufacturers for the formation of a slip-coating on wares. If used in this manner it would have to be applied to a clay of semi-refractory or refractory character for the reason that the paint clay itself does not vitrify below cone 3, and to use it on a low-grade clay it would have to be mixed with fluxing material which would probably not pay. The physical properties of the clay are briefly as follows: Air-shrinkage, 8%; incipient fusion at cone 03 with a total shrinkage of 14%; at cone 1 total shrinkage, 17%, and the clay still absorbent; vitrification occurs at cone 3 with a total shrinkage of 20%. The clay burns red, and the color deepens as the temperature increases.

A yellow ocher clay of good color is found on the Randall estate (8853, Relay 1). The material occupies a position at the base of the Arundel. If ground sufficiently fine it could no doubt be used in the manufacture of paint, but in its natural condition it is somewhat sandy.

A vast deposit of reddish-drab clay is found on the property of the Crown Cement Works at Lansdowne (8881, Relay 1). It is used in the manufacture of Portland cement.

A bed of plastic red clay occurs on the Randall estate at Halethorpe (8960, Relay 1). The material is known locally under the name of potter's clay and is no doubt suitable for the manufacture of common red earthenware.

Anne Arundel County.—It can be said in a general way that the Arundel clays are found chiefly in the northwest corner of the Relay quadrangle. In the region to the northeast of Patapsco station, on the Pennsylvania Railroad, and in the Hanover district, there are a number of iron mines yielding vast quantities of clay. One of the most notable examples is at M. Reynolds' iron mine on Piney Run, 1⅜ miles south of Hanover (Relay 1).

PANORAMIC VIEW OF BUSEY'S BRICK YARD, BALTIMORE.

BANK OF ARUNDEL CLAY ON THE RIGHT, FORMERLY WORKED FOR IRON ORE.

In this county the Arundel formation is specially well developed, forming often great banks containg ore nodules, though at times clays of better grade and free from iron ore are met with.

One and a half miles east of Laurel an offshoot of an Arundel ore mine is being worked for brick. There are also extensive beds of Arundel clay in the vicinity of Patuxent station, while a very plastic, red-burning potter's clay occurs on the property of Charles Needer, 1 mile northeast of Patapsco station on the Pennsylvania Railroad (8819, Relay 1).

Among other localities where iron-ore clays may be found may be mentioned Jessups (Laurel 6), Annapolis Junction (Laurel 6), and in the vicinity of Dorsey (Relay 1).

Howard County.—One of the best known deposits of clay found in the Arundel formation occurs near Dorsey (233, Relay 1, "Timberneck Mine"). The material is known as potter's clay but has hardly sufficient tensile strength or plasticity to permit its being used alone for this purpose. It is, however, fairly refractory in its character and consequently suitable for employment in fire-brick mixtures. The material is an open-textured, sandy clay, which slakes quite fast in water. In mixing it the amount of water required for tempering is but 22%, and the bricklets made from this have an air-shrinkage of 5%. The average tensile strength is low, being but 60 pounds per square inch. In burning at cone 4 there is an additional shrinkage of 1%, making a total of 6%, the color of the clay being whitish and the body sufficiently hard to resist scratching with a knife. The clay vitrifies at cone 12 with a total shrinkage of 12%, its point of viscosity as determined in the Deville furnace is the same as cone 27.

This material, aside from the uses already found for it, might find favor with the manufacturers of buff terra cotta, and floor tile.

A very plastic, though somewhat gritty potter's clay, is found at the Hobbs' iron mine, Hanover (8243, Relay 1).

A deposit of brick clay is worked at the Diven estate iron mine at California, between Contee and Muirkirk (8200, Laurel 8). This is at a lower level than the clay at the Front Brick Works.

Still another large deposit of brick clay, of this age, is found at the Ashland iron mine 1½ miles northeast of Jessups (8861, Laurel 6).

Prince George's County.—The Arundel extends along the southeastern border of the area underlain by the Patuxent with offshoots up the valleys to the southeast. In these valleys, it outcrops along the shores and in the bluffs, but does not always extend to the surface for it is overlain by the Patapsco.

Iron-ore is found in the Arundel clays at many points in Prince George's county, and these clays are used to some extent for bricks.

Extensive deposits of Arundel brick clay are known to occur on the Peterson estate west of Contee, and at the iron mine immediately east of Annapolis Junction. This last deposit is very thick. It resembles the Raritan clay but probably has more ferric oxide (179, Laurel 6).

Patuxent Formation.

This formation has been so-called from its typical development in the upper valleys of the Little and Big Patuxent rivers. It is the basal formation of the Coastal Plain series and therefore lies directly on the crystalline rocks of the Piedmont Plateau. It forms a broad belt near the landward margin of the Coastal Plain and has been traced from Cecil county across Harford, Baltimore, Anne Arundel and Prince George's counties through the District of Columbia into Virginia.

While the deposits are mostly sand, often of high purity, still beds of sandy clay sufficiently plastic for the clay-workers' use are occasionally found. Stoneware clays are also at times met with in this formation. The thickness of the Patuxent is estimated at about 150 feet. As a clay-yielding formation the Patuxent is less important than the Patapsco, Arundel or even Raritan. The sands are well shown in Plate LII, Figs. 1 and 2.

Regarding its areal distribution, it can be said that since the Patuxent rests on the crystalline rocks along the eastern border of the Piedmont region, it forms a strip of variable width along the western border of the Coastal Plain.

Cecil County.—Although occurring at a number of points in this county, still the Patuxent carries very little clay of commercial value,

FIG. 1.—ARUNDEL CLAYS AT YARD 17, BALTIMORE BRICK COMPANY, HERRING RUN, BALTIMORE COUNTY.

FIG. 2.—ARUNDEL CLAY USED FOR TERRA-COTTA, WASHINGTON ROAD, BALTIMORE COUNTY.

being usually very sandy. Here and there it contains many grains or pellets of white clay, which have been derived from the underlying beds of kaolin. This can be well seen at the beds of the Maryland Clay Company, near Northeast.

Additional exposures of Patuxent clay occur along the high road one mile due east of Roach Point in Elk Neck, where on a steep hillside there are abundant outcrops of chocolate clays overlain by variegated ones. They are similar in appearance to those found on Ford's Hill (83, Elkton 7).

Harford County.—Here the western border of the Patuxent passes approximately through Jerusalem Mills and Harford Furnace, and extends up to Webster. On the southeastern side it generally extends down to the Baltimore and Ohio Railroad. On the whole the beds are rather sandy, but near the base of the formation as exposed in the railroad cut at Sewall there is a deposit of creamy-white plastic clay, which is supposed to be not less than 6 feet thick. Preparations have been recently begun to ship this material.

A very talcose and micaceous clay (5750, Gunpowder 3) known as "soap clay" is found forming a bed six feet thick in the Otter Point cut near Sewall on the Baltimore and Ohio Railroad. It mixes up with 21% of water to a somewhat lean mass, whose air-shrinkage is 5%. The tensile strength is 30 pounds per square inch. The material is semi-refractory, burning buff at cone 8, with a total shrinkage of 12%. It becomes viscous at cone 27. The clay is about to be worked. There is probably quite a deposit of the material. In places it is considerably iron-stained, but these parts might be thrown out.

Another sample of material from the Otter Point cut was tested for its refractoriness and found to be the same as cone 27 (5768, Gunpowder 3).

Another deposit of buff to white clay apparently referable to the Patuxent occurs along the shore of Gunpowder river, above the north end of the Philadelphia, Wilmington and Baltimore Railroad. The deposit is probably ten feet thick, and stained here and there with limonite.

A pink, sandy clay 4 feet thick crops out below Otter Point land-

ing (180, Gunpowder 3). There is 8 feet of overburden, but the clay is quite refractory, only vitrifying at cone 27.

At Jackson Hill, 1½ miles northwest of Aberdeen there is exposed an extensive bed of black and chocolate clays apparently referable to the Patuxent. The black clays resemble those exposed on Broad Creek, Cecil county.

Baltimore County.—The Patuxent beds have been encountered at several points within the city limits of Baltimore, notably at the new Courthouse. These deposits, indeed, are often worked for building sand. In many instances the materials found combine the qualities of sufficient refractoriness and low shrinkage to adapt them to the manufacture of terra cotta. These properties are well shown by the following physical tests which were made on a sample taken from the foundations of the new Courthouse. The material is a sandy clay (237, Baltimore 8) which in its natural condition is of a buff color, and although gritty, does not slake very rapidly. At the same time it possesses moderate plasticity but is somewhat refractory in its character. The air-shrinkage is 5%, at cone 4 the total shrinkage is 6%, but it does not assume a hardness of 6 until a temperature of the fusing point of cone 6 is reached. At cone 8 it burns to a hard body of light buff color, and at cone 10 the product is good and hard, with a total shrinkage of 9% and a buff color. The material while it lasted was used by the Burns and Russell Company in the manufacture of terra cotta, and produced excellent results when mixed with a more plastic clay. With the abundance of sandy clays in the Patuxent, there seems to be no reason why additional beds of the clay should not be found at other localities. Indeed, similar but usually somewhat finer material is found at several places in the Raritan, notably in connection with the glass-sands along the Severn River. The Patuxent sands are also exposed at several points south of Baltimore, and are frequently found immediately under the iron-ore clays of the Arundel formation.

They may show considerable variation from point to point, a bed of pure sand passing horizontally into one of sandy clay, within a distance of 100 feet.

FIG. 1.—PATUXENT SAND NORTHWEST OF CURTIS BAY JUNCTION, BALTIMORE COUNTY.

FIG. 2.—PATUXENT SAND CAPPED BY BED OF PAINT-CLAY, SHELL ROAD, SOUTH OF BALTIMORE.

Paint clay is found in a deep ditch on the McIntosh estate near Lansdowne (8262, Relay 1).

Anne Arundel County.—Clay of a refractory nature is found on Deep Run, on the H. Brown estate at "Timberneck," Anne Arundel county (8960, Relay 1). Its thickness is probably 10 feet and it is of considerable horizontal extent. Its fusibility lies slightly higher than cone 27.

Howard County.—Near Jessups, on the Baltimore and Ohio Railroad, white clay is found on the Hartsock estate (8777, Laurel 6). The material seems to underlie the iron-ore clays and is no doubt refractory. It outcrops in the stream bed.

Again white clay of very refractory character is found in the Baltimore and Ohio cut near Savage (8320, Laurel 6). It vitrifies at cone 27, and is therefore fairly refractory.

Prince George's County.—Here the Patuxent is found at Burtonville and Spencerville, and extends to Laurel on the north. It is also found in the valley of the Big Patuxent. From Laurel it extends southwestward to Washington, following the line of the Baltimore and Ohio Railroad. At the latitude of Washington, the width of the Patuxent outcrops is about the same as the city, but below this it extends as a little strip down the east side of the Potomac.

Throughout this area, there is a variable thickness of Columbia and Lafayette covering, while around Washington it is overlain by isolated patches of Arundel.

THE CARBONIFEROUS SHALES.[1]

The Carboniferous rocks are found in the western part of the State in Garrett and western Allegany counties. These are divisible into a number of different formations, as has already been mentioned. It may be said of these in general that they consist of a series of sandstones and shales with some beds of coal and limestone. The shales are sometimes refractory, but more often they contain sufficient impurities to make them easily fusible. The characters of the different formations are as follows:

[1] In preparing the portion relative to the Carboniferous, the writer has drawn freely on the Allegany Report of the Md. Geol. Survey.

Dunkard Formation.

This formation is about 400 feet thick and consists of shales and thin limestones. Its beds lie stratigraphically above the Koontz or Waynesburg coal. An outcrop (133, Frostburg 4) of the shales is to be seen along the road to the north of the pumping shaft of the Consolidation Coal Company. The material is a black, rather soft shale, which does not seem to mellow down very rapidly to a clay.

Monongahela Formation.

The base of this formation is distinctly marked by the presence of the Pittsburg coal while its upper limits are located by the roof of the Koontz (Waynesburg) coal. Its total thickness is about 250 feet. The most prominent development of the formation occurs south of Frostburg. It is composed chiefly of sandstone and shales. The latter are said to be both arenaceous and argillaceous and have a color which varies from light gray to green or brown or sometimes even black. Beds of limestone occasionally occur.

An outcrop of Monongahela shale, from near the top of the formation is to be seen in the cut just south of the pumping station of the Consolidation Coal Company, and north of Borden Shaft. The material at this point is very sandy and associated with limestone.

A more shaly, but still rather sandy bed, outcrops on the western edge of Frostburg along the National Road.

It is doubtful if the Monongahela shales will be found adapted to brick making.

Conemaugh Formation.

This formation, which was formerly called the Barren Measures, consists largely of beds of shale. A sandstone, sometimes of rather massive character, is generally found near the bottom and is apparently equivalent to the Mahoning sandstone of Pennsylvania. Sometimes another sandstone occurs 20 to 30 feet below the top of the formation. The Conemaugh contains other sandstones and also several beds of massive limestone whose occurrence in association with the shale may prove to be of commercial value for cement manufacture.

The shales are usually quite argillaceous and sometimes associated with coal, although at times they are perhaps rather more bituminous or carbonaceous than would be desired for material to be used in the manufacture of clay products. A section in the upper part of the formation is found along the Potomac gravity plane and is as follows:[1]

SECTION AT THE POTOMAC PLANE, ALLEGANY COUNTY.

	Feet.	Inches.
Black shale		10
Very coaly shale		8
Black, somewhat coaly shale	1	8
Impure coal	2	8
Black shale with very thin coal streaks		4
Coaly shale		1
Coal, apparently all good	2	4
Shale, dark above, gray lower down	1	5
Clay		7
Massive bluish gray argillaceous limestone	2	1
Massive light gray argillaceous brecciated limestone	1	9
Very argillaceous limestone	4	6
Soft, weathered shale		4
Iron-ore band		4
Black, coaly shale	2	

Another detailed section of the Conemaugh was obtained by Professor Chas. S. Prosser, of the Maryland Geological Survey, on Phoenix Hill, 2 miles below Barton.[2]

Under the Franklin coal near Midland there is an exposure of shale three feet thick which grinds up to a fairly plastic mass with 17% of water. The bricklets made from this had an air-shrinkage of 4%. At cone 8 the total shrinkage was 7%, and the clay incipiently fused with a gray buff color. It is not a fire-clay, for at cone 27 it is thoroughly viscous.

One large outcrop of the Conemaugh shale is to be seen between the two wagon bridges on the east side of Georges Creek at Barton (131, Grantsville 9). The bed is at least six feet thick, above the creek-level and extends below for a short distance. It is overlain by a bed of limestone and over this is a layer of sandstone. The material is a fissile, soft shale with numerous siderite concretions.

[1] Md. Geol. Survey, Report on Allegany Co., p. 119. [2] *Ibid*, p. 122.

Another easily accessible outcrop is along the road to Mount Savage, and due north of Frostburg (275, Frostburg 2). The shale outcrop is about 250 feet below the top of the formation and is seen in a pit used to supply road material. The shale forms a bluff about 20 feet high, and the sample represents the average of the lower 15 feet of this. At the outcrop there was no means of telling anything about the properties of the different bands, nor did it seem economical to work one without the other. The ground sample was made up into bricklets which were very granular, and took about 18% of water for mixing. At cone 01 the clay shows incipient fusion, and at cone 4, the result is a bricklet of speckled red and cream grains, showing that all the shale layers in the section do not burn alike. The light-colored grains are not to be looked upon as refractory particles, for they show signs of fusion in the bricklet. The total shrinkage was 5%. The clay, owing to its lean character would be of little use by itself, but if some other very plastic clay in its neighborhood were being used for brick manufacture it could be mixed in with it.

The composition of this shale is:

Analysis of Shale, North of Frostburg, Allegany County.

Silica	51.05
Alumina	28.60
Ferric oxide	3.75
Lime	3.80
Magnesia	1.24
Alkalies	.50
Ignition	10.85
Total	99.79
Total fluxes	9.29

The high fluxes would indicate that the clay is more fusible than it really is, but this is due to the fact that they are not evenly distributed, but are concentrated in certain layers.

Allegheny Formation.

Stratigraphically this formation is considered identical with the Allegheny series of Pennsylvania, and immediately underlies the Conemaugh, and like it, underlies most of the Georges Creek coal basin. It outcrops on the eastern side of the basin high up on the western slopes of Dans and Little Allegheny mountains. In a simi-

lar manner its western area shows along the eastern edge of Savage Mountain.

The formation contains many beds of shale which are interbedded with deposits of sandstones and also several seams of coal. The following section taken from the Allegany County Report, page 116, indicates the number and position of several of the shaly deposits.

SECTION AT FRANKLIN GRAVITY PLANE, ALLEGANY COUNTY.

	Feet
Sandstone, apparently the Mahoning	
Concealed	25
Sandy ferruginous shale	60
Sandstones and concealed	50
Sandstone, flaggy near the top	60
Shale	6
Coal (Davis)	6
Concealed	30
Flaggy or shaly sandstone	61
Coal (Parker)	1
Shale	19
Conglomeratic sandstone of Pottsville	

This section shows therefore that there are several shaly beds having a definite stratigraphic position close to the coal seams mentioned in the section.

A more detailed section is as follows:

SECTION AT FRANKLIN VILLAGE, ALLEGANY COUNTY.

	Feet
Massive sandstone	
Greenish shaly sandstone	55
Massive sandstone	24
Ferruginous shale, showing spheroidal weathering	3
Thin black and brown shales	8
Grayish green shale	10
Fine grayish green shale	4
Arenaceous shale	9
Greenish sandstone and shale	26
Shaly sandstone	6
Fine shale and concealed	9
Shaly sandstone	13½
Concealed	30
Coal (Davis)	6
Sandstone, shale and concealed	7
Flaggy sandstone	16
Massive sandstone	4
Shale	2
Coal ("split-six")	3
Concealed	90

While of course all of these shales may not grind up to materials of sufficient plasticity for the manufacture of clay products, at the same time the composition of many of them may be such that they can be used in the manufacture of Portland cement.

A shale outcrop occurring about 75 feet from the top of the formation and half way between the Davis and Thomas coal seams is well exposed at the top of the hill along the road north of the Franklin schoolhouse for a distance of about 600 feet. The material is a medium soft shale fully 10 feet thick and well located for working (284, Grantsville 9).

It is a rather hard shale which grinds up with water to a mass of moderate plasticity. It would no doubt work for the manufacture of brick, for it possesses sufficiently plastic qualities to mold and burns to a good red color. Incipient fusion occurs at cone 1, vitrification between cones 5 and 6, but at as low a point as cone 03 the clay would make a good red common brick. The shrinkage on vitrification is 8%.

At the Merrill mine near Westernport there is found an eight-foot bed of shale overlying the Davis coal seam. It is of a dark gray color and very fine-grained in its nature, containing minute flakes of mica, together with considerable organic matter. It does not weather down as easily as shale exposed near the Cumberland and Pennsylvania Railroad bridges. It is no doubt quite fusible. Where weathering has acted on the clay there is considerable limonite staining and the shale also seems to contain an abundant quantity of soluble salts.

Soft shale exposures also occur on the west bank of Georges Creek, Allegany county, on a steep slope opposite Gannon's Plane. The first shale bed is at the bottom of the slope, which is below the "split-six" coal seam. This shale is very sandy in its nature, but is probably eight feet thick. About four feet further up the slope the "six-foot" coal seam outcrops, and below it is a shale similar to that seen at Merrill's mine. It also is rather slaty in its character.

A short distance further up the valley, at a point where the new drift was being cut by Mr. Gannon on the west side of Georges Creek, just opposite the schoolhouse (281, Grantsville 9), there is an abundance of a hard, dark gray shale. This material is probably very close

FIG. 1.—PATAPSCO STONEWARE CLAY, NEAR CARPENTER'S POINT, CECIL COUNTY.

FIG. 2.—SHALE BED AT GANNON'S NEW CUT, NORTH OF WESTERNPORT, ALLEGANY COUNTY.

to the six-foot seam above, and underlies it stratigraphically. A tunnel has been driven in 260 feet and most of it in this shale (Plate LIII, Fig. 2). The thickness of the shale is probably not less than eight feet and is overlain by sandstone.

The material in its natural condition is very hard and dense and consequently not only resists grinding, but also mixing to a plastic mass, so that if used by itself it would be of limited value to the manufacturer of clay products. Since there are, however, abundant supplies of limestone not far from this locality it would seem that the material might be adapted to the manufacture of Portland cement, for an inspection of the analysis given below shows that it is not unlike many of the shales or clays employed in the manufacture of this hydraulic substance. Its composition is as follows:

ANALYSIS OF SHALE FROM GANNON'S DRIFT, ALLEGANY COUNTY.

Silica	56.50
Alumina	22.90
Ferric oxide	6.37
Lime	1.60
Magnesia	1.58
Alkalies	1.60
Organic matter	10.00
Total	99.55
Total fluxes	10.55

Pottsville Formation.

The Pottsville formation is the lowest division of the Coal Measures, and forms the ridges of the hills around the coal basins. The section shows beds of conglomerate and sandstone interbedded with beds of shale, and thin layers of coal. In this formation there are found not only beds of shale, but also valuable deposits of both flint and plastic fire-clay. The following is an average section:

SECTION OF THE POTTSVILLE FORMATION, WESTERNPORT, ALLEGANY COUNTY.

	Feet.
Allegheny shales	
Massive sandstone, Homewood	26
Concealed, but with abundant fragments of flint fire-clay in the talus.	64
Massive sandstone	6
Concealed	29
Massive quartzose sandstone	20

	Feet.
Sandstone	4
Concealed	28
Black shale	5
Sandstone	1
Dark shales	12
Coal	1
Dark gray shale	4
Coal	1½
Dark gray shale	4
Sandstone	4
Concealed	16
Dark gray shales	10
Sandstone	1
Concealed	40
Massive sandstone	20
Shale	2
Sandstone	10
Black shale	25
Coal	⅔
Black shale	4
Sandstone	25
Shale and sandstone	6
Coal	1¼
Sandstone	4
Mauch Chunk shales	
	374½

Another section measured by Professor I. C. White in Pennsylvania just north of the Maryland line is as follows:

	Feet.	Inches.
Massive sandstone	75	
Mt. Savage coal	4	
Mt. Savage fire-clay	7	6
Conglomerate sandstone	125	
Dark shaly sandstone	10	
Shale	1	
Coal and shale		8
Impure fire-clay	10	
Dark shales with iron-ore	20	
Massive sandstone	35	
Total thickness	288	2

This indicates the position of the Mount Savage fire-clay very well. The importance of this bed of Mount Savage fire-clay cannot be overestimated for, owing to its well-marked stratigraphic position,

and great length of probable outcrop in both Garrett and Allegany counties it should in the future be opened up at many points. The accompanying map, Plate LIV, gives approximately the position of the outcrop. Owing to the heavy covering, outcrops are scarce, but knowing the position of them they can be prospected for at much less expense. Already the bed has been opened up at two points on Savage Mountain, which are respectively west of Frostburg, and Mount Savage; and also on Little Allegheny Mountain west of Ellerslie.

The deposit has also been found outcropping near Blaine, and at Swallow Falls. At Swallow Falls the clay is exposed in a ledge along the track of Knabb and Co.'s lumber road at a point near the highway and in close proximity to a drift which has been run into the Mount Savage coal.

The plastic shale immediately overlies the coal, while over this in places the flint clay is found. This latter begins as a thin streak near the entrance to the drift, but increases in thickness to the south, until it is fully three feet. It is somewhat darker in color than the Savage Mountain flint clay and not quite so lustrous. Further exploitations will very probably develop a considerable quantity of this material.

A test made of the flint clay shows that at cone 27 in the Deville furnace it is unaffected, the bricklet barely showing any signs of incipient fusion and thereby equalling the Savage Mountain clay in its fire-resisting qualities.

Its chemical composition is:

Analysis of Flint Clay, Swallow Falls, Garrett County.

Silica	61.00
Alumina	26.36
Ferric oxide	.83
Lime	.21
Magnesia	.10
Alkalies	Tr.
Water	11.60
Total	100.04
Total fluxes	1.14

A sample of the shale clay associated with the flint was also tested. It is less plastic when fresh, but exposure to the weather would no doubt make it mellow down to a very soft mass.

It mixes up with 18% of water to a mixture of low plasticity, with a tensile strength when air-dried of 35 to 40 pounds per square inch. The air-shrinkage is 2½%. When burned to cone 4 its total shrinkage is 5%. At cone 8 it burns buff, giving a hard, moderately absorbent product with a total shrinkage of 7%. At cone 27, in the Deville furnace, it shows incipient fusion. Its chemical composition is:

ANALYSIS OF SHALY FIRE-CLAY, SWALLOW FALLS, GARRETT COUNTY.

Silica	46.10
Alumina	38.05
Ferric oxide	1.05
Lime	.39
Magnesia	.60
Alkalies	..
Water	12.95
Total	99.14
Total fluxes	2.04

Another locality at which there is an outcrop of the Mount Savage bed of flint clay, excellently situated for working, is along the Potomac river, at a point one mile above Blaine. The section involves, according to Dr. G. C. Martin:

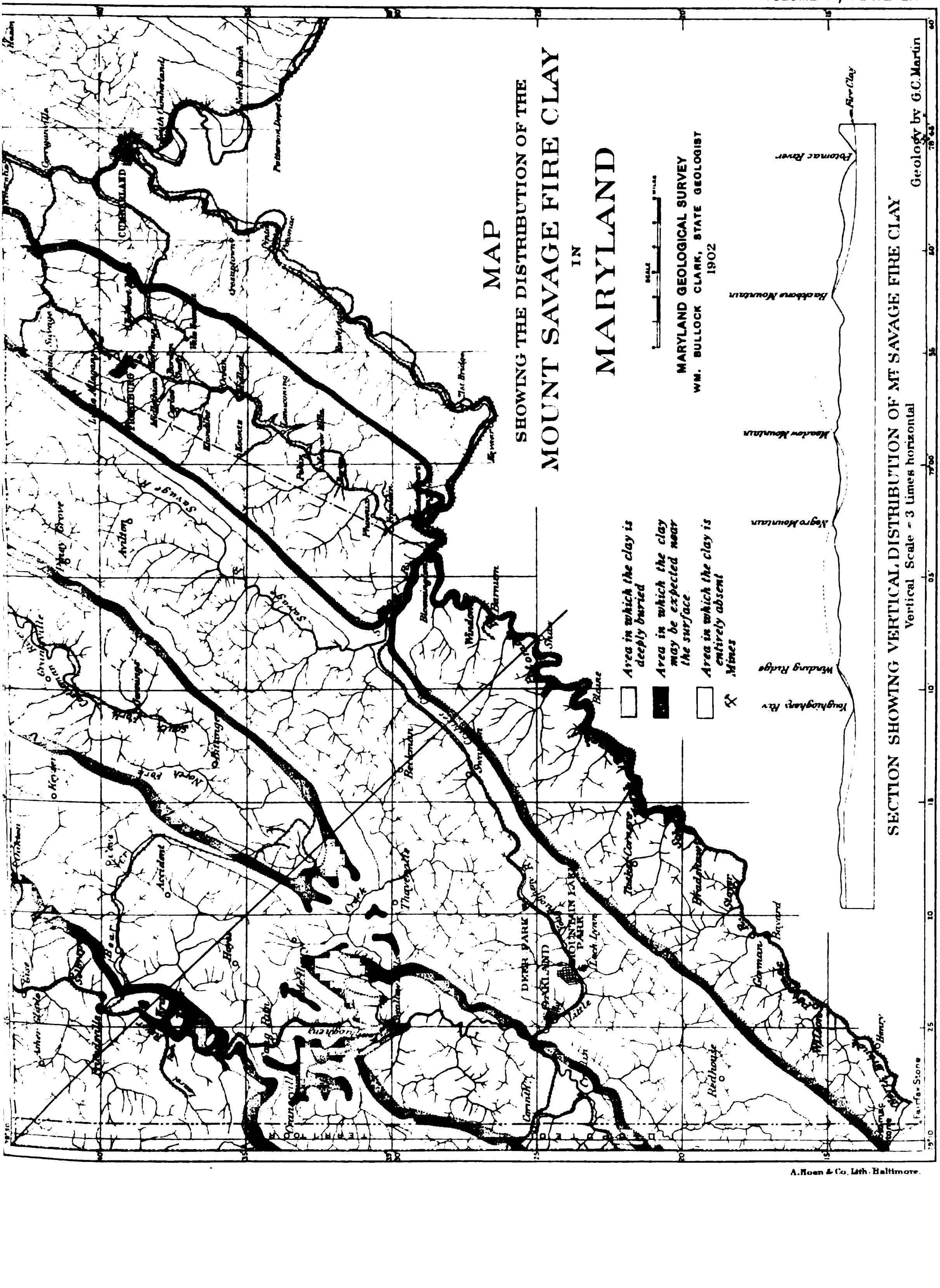
SECTION ONE MILE ABOVE BLAINE, GARRETT COUNTY.

Thin coal	
Flint clay	6±
Soft clay	8
Concealed	

It is well located for working, since it is in the river bank opposite the railroad and near a bridge over which the output of two coal mines is taken to the railroad. Both kinds of clay were submitted to a test.

The flint clay is very refractory, and at cone 27 is barely incipiently fused.

The plastic shale clay ground up to a mass of fair plasticity, which required 15% of water for tempering. The bricklets made from it had an air-shrinkage of 3½%. At cone 4 its total shrinkage was 5½%. At cone 8 the clay burned to a moderately dense buff product, with a total shrinkage of 7%, and somewhat absorbent character. At cone



A. Hoen & Co. Lith. Baltimore.

27 it was incipiently fused, and was slightly more refractory than the Mount Savage plastic clay mined on Savage Mountain.

The composition of the flint clay is:

ANALYSIS OF FLINT CLAY, NEAR BLAINE, GARRETT COUNTY.

Silica	45.40
Alumina	38.90
Ferric oxide	1.01
Lime	.31
Magnesia	Tr.
Alkalies	Tr.
Water	15.20
Total	100.82
Total fluxes	1.32

For purposes of comparison some samples of the Savage Mountain clay were also tested.

FLINT CLAY FROM MOUNT SAVAGE (273, Frostburg 1).—The uses of this material are too well-known to need mention here and the only test which was made on this material was one for refractoriness which, however, would also seem rather unnecessary perhaps. A piece of the clay was heated up to cone 27 with the result that at this temperature incipient fusion had barely begun, indicating very well the highly refractory nature of the material. Its composition is:

ANALYSIS OF FLINT CLAY, MOUNT SAVAGE, ALLEGANY COUNTY.

Silica	56.147
Alumina	33.295
Ferric oxide	.59
Lime	.17
Magnesia	.115
Water	9.680
Total	100.000
Total fluxes	.875

PLASTIC CLAY FROM THE SAVAGE MOUNTAIN MINE (268, Frostburg 1).—The plastic and also the flint clay occur in this mine. A sample of the plastic variety was put through a partial test to determine its general character. It is found to burn to a hard brick at a comparatively low temperature, viz., cone 2, with a total shrink-

age of 8%, while at cone 10 it is nearly impervious with a total shrinkage of 10%. The color in each case is buff. When heated to cone 27 in the Deville furnace, it was thoroughly vitrified, indicating thereby that it is not as refractory as the flint clay, which is not more than incipiently fused when heated to this temperature.

Mauch Chunk Formation.

The Mauch Chunk formation is perhaps the richest in shales, and therefore of interest to the clay-worker. It flanks the ridges of western Allegany and eastern Garrett counties, and grades gradually downward into the Greenbrier deposits. The formation consists largely of red shales, which are interbedded with flaggy, red-brown and fine-grained sandstones. Both the shales and sandstones are often micaceous. Thin beds of carbonaceous shales are found in places near the top of the formation. The total thickness of the Mauch Chunk is from 650-800 feet.

A sample of Mauch Chunk shale, collected on the west side of Savage Mountain (282, Frostburg 1), gave the following results when tested: Although a rather lean shale, of granular nature, it mixed up into bricks, which burned to a good red color, and desirable density, similar to the Jennings shale utilized at Cumberland, but showing slightly greater shrinkage.

It took 19% of water to work it up. The air-shrinkage was 4%. At cone 01 incipient fusion occurred, with a total shrinkage of 8%; the clay vitrified at cone 4, with 9% total shrinkage.

Greenbrier Formation.

This has a thickness of about 200 feet and extends across the two counties mentioned, practically parallel with the Pocono outcrops. It consists of a series of limestones, sandstones and shales.

The best sections of the formation are to be seen at the mouth of Stony Run below the water tank on the West Virginia Central Railroad, two miles southeast of Westernport. While shale beds are abundant most of them are very sandy and few of the beds show sufficient thickness to make them of considerable commercial value.

Pocono Formation.

This forms the basal member of the Carboniferous. It extends from southwest to northeast across western Allegany and Garrett counties and consists chiefly of flaggy sandstones. Deposits of black shale are sparingly found.

THE DEVONIAN SHALES.

The Devonian formation is represented in Allegany and Garrett counties by a great series of shales, shaly sandstones and sandstones.

In some cases the shales have been so altered by folding that they develop little or no plasticity when ground and mixed up with water, while at other times, they are capable of excellent service in the manufacture of clay products.

The *Hampshire* or uppermost formation of the Devonian contains from 1900 to 2000 feet of shales and sandstones, but they are probably too silicious in most instances to make a good brick.

The *Jennings* which is the next underlying formation is far more promising. It, too, forms beds of shales and sandstones which have an aggregate thickness of from 3500 to 5000 feet. The layers are often greenish-yellow in color, although near the base some thin black shales occur. A large thickness of Jennings shale is passed over in driving eastward from Grantsville to Frostburg.

The same shale is also well-exposed near Cumberland where it is used in the manufacture of brick.

The deposit, as exposed in the bank of the Queen City Brick Company, is separable into three benches, viz.: two lower massive ones, and an upper one of weathered material and higher plasticity. A test made of the bottom shale from the pit of the paving-brick works at Cumberland indicates that if used by itself it would work poorly owing to its lean, granular character when ground up and mixed with water. The desired plasticity is obtained by mixing some of the weathered portion of the shale with the fresh layers.

The results of fire-test on this material are, that it burns to a good red at moderate temperature, with low shrinkage, and vitrifies rather easily. Thus the sample tested worked up with only 15% of water,

but had very little plasticity. At cone 01, the total shrinkage was 5%, and the color good red; vitrification occurred at cone 3, with a total shrinkage of 7%. The shale burns to a very solid body.

The chemical composition of this shale is:

Analysis of Jennings Shale, Cumberland, Allegany County.

Silica	68.30
Alumina	17.50
Ferric oxide	4.00
Lime	.80
Magnesia	.65
Alkalies	3.10
Ignition	5.10
Total	99.45
Total fluxes	8.55

The high percentage of iron oxide accounts for the deep red color on burning and the easy fusibility of the shale.

Weathered shale from the paving-brick works at Cumberland, which forms a bed from five to six feet thick in the upper part of the quarry, as already mentioned, has more plasticity than the underlying material. This also serves to increase the shrinkage and tensile strength. In working up the shale 25% of water was required and this yielded a mass of moderate plasticity which at cone 5 burned to a hard brick of red color and with a total shrinkage of 6%, the product being sufficiently hard to resist scratching with a knife. When burned to cone 2 the clay was nearly vitrified, the color deep red, and the total shrinkage 10%. These facts form the basis for an interesting comparison of the properties of Nos. 271 and 272, which represent the lower-lying and unweathered layers of the same pit.

THE SILURIAN SHALES.

With few exceptions the Silurian rocks of Maryland do not seem to be adapted to the manufacture of clay products, unless they have been changed into residual clay by weathering agencies. This is not because of the absence of shaly formations, but because those which do exist have been so altered by folding and metamorphism as to lose their plastic qualities.

FIG. 1.—GENERAL VIEW OF WORKS OF QUEEN CITY BRICK AND TILE COMPANY, CUMBERLAND, ALLEGANY COUNTY.

FIG. 2.—PORTION OF SHALE BANK OF QUEEN CITY BRICK AND TILE COMPANY, CUMBERLAND, ALLEGANY COUNTY.

One of the few exceptions is the *Clinton* shale which outcrops on the hill above the cement works at Pinto. At this locality (278, Frostburg 8) there are to be found considerable exposures of a soft, flaky shale, which in places tends to weather down rather easily. It seems to be the only shaly material at this locality which contains any plastic characteristics, the other shale outcrops farther down the hill, being of too silicious and of too compact character to lend itself to the manufacture of clay products. While a sample of this material was collected still it was not put through a complete test and simply enough of an examination was made to indicate its character in a general way. It grinds up quite readily and requires comparatively little water to mix it, namely 24%, but the mixture is not highly plastic, although probably as much as that which is obtained by grinding and wetting the shale found at Cumberland, and there used in the manufacture of paving brick.

The shale at Pinto has an air-shrinkage of about 3%. At a comparatively low temperature, namely, cone 3 it burns to a good hard product of a red color, with a total shrinkage of 8%. This, however, is a little higher temperature than would be reached in the manufacture of most brick.

ALGONKIAN RESIDUAL CLAYS.

The clays belonging to this age are all residual in their nature. At times the upper portions of the deposits have been caught up by the currents which deposited the Patuxent sands and clays, and worked over into a stratified form with the admixture of comparatively little sedimentary material.

Kaolin in Cecil County.

These residual Algonkian clays have attracted considerable attention, especially in Cecil county, for the reason that they have been derived from feldspathic gneisses comparatively free from minerals containing iron. The residual clays thus formed, are therefore to be classed as kaolins, on account of their whiteness and white-burning characters. It must be said that the kaolin industry of Maryland has not proceeded beyond the prospecting stage, there being but one

company at work actually mining and washing the material. Kaolin has been located, however, at many points as will be noted beyond, and in the next few years there should be a great increase in clay-mining in this region. The Cecil county kaolin deposits are a continuation of those of Delaware, which have been so extensively drawn on in the manufacture of white ware.

Owing to the presence of beds of Patuxent and Columbia age the kaolin is rarely exposed at the surface, and consequently is usually found either in making road or railroad cuttings or in the digging of wells. Where it is thus encountered or its presence suspected, the extent of the deposit is further determined by test pits or borings.

The amount of overburden varies, being in some cases as little as two feet, in others as much as twenty. The depth of the kaolin is also quite variable, and depends naturally on the depth to which weathering has decayed the parent rock, and also on the extent to which the deposit has been eroded by the currents which deposited the Patuxent sands. These sands are often of a refractory character and are sold as fire sands. They represent the quartz and partially decayed feldspar particles which were present in the residual clay. The clay particles being very fine have either been floated off, or balled up into little plastic lumps from ½ to 1 inch in diameter, which are found in the sands.

Maryland Clay Company.—This company is the only one which is at present mining and washing clay. Its pits are located about 1 mile southwest of Northeast station, and between the highway and the Philadelphia, Wilmington and Baltimore Railroad (1, Elkton 4).

The kaolin is a decomposed feldspar mica gneiss overlain by Patuxent sands on the western side of the pit and by Patuxent and Pleistocene deposits on the eastern side.

These sands, which are often quite micaceous, vary in thickness from 10 to 40 feet, and have to be stripped off before the kaolin can be dug. The stripping is done with a steam-shovel. Between the kaolin and sand there is often a layer of sandy, micaceous clay, more or less mottled with limonite stains. This is sometimes sold for making saggers.

FIG. 1.—PIT OF MARYLAND CLAY COMPANY, NORTHEAST, CECIL COUNTY.

FIG. 2.—KAOLIN OUTCROP IN SUTTON'S CUT, NORTHEAST OF PERRYVILLE, CECIL COUNTY.

The kaolin pit is a long opening running about northwest and southeast, with the washing plant near the latter end.

Two grades of kaolin are recognized, the second having some iron stains. Both grades are washed, but the lower quality is sometimes sold in its crude form for fire-clay or sagger-clay.

The method employed in washing the clay is not unlike that used at other works and consists in first dumping the crude kaolin and water on the sand-wheels. These, as previously described, remove much of the sand, and the remainder which remains in suspension together with the kaolin is washed along the troughing, where most of the fine sand is dropped before the settling tanks are reached. There are about 700 feet of troughing which is in 120-foot lengths. There are 3 settling tanks, from which the kaolin, after settling, is pumped into the filter press. Of these there are three, of Robinson make.

The sand which is separated is thrown away. The kaolin is used chiefly for paper manufacture.

The washed product forms 30% of the quantity mined.

The pressed clay is dried on racks in the open air.

It is probable that with the development of the kaolin field in Cecil county additional washing plants will be erected. The works are shown in Plate LVII, Fig. 1.

The washed clay from the pit of the Maryland Clay Company shows the following characteristics: There are considerable quantities of small mica scales, whose presence is undoubtedly shown by the silica percentage found on analysis of the material as given below, still the material, which is used chiefly in the manufacture of paper, is very refractory, for there is not sufficient mica or undecomposed feldspar present to act as a powerful flux. As is the case with most kaolins the tensile strength of the material is very low and, therefore, no briquettes were made. Some bricklets of the material yielded the following results: Air-shrinkage, 1½%. When burned to cone 5 the total shrinkage was 9%, but the bricklet was still easily scratched, and had a very white color. At cone 10 the clay was barely scratched with a knife, and the total shrinkage 14%. The color was whitish.

At cone 27, in the Deville furnace, the material had preserved its form perfectly, and showed signs of incipient vitrification. In refractoriness it is fully equal to many of the best kaolins put on the market.

Its composition is:

Analysis of Washed Kaolin, Northeast, Cecil County.

Silica	55.65
Alumina	30.53
Ferric oxide	.97
Lime	.75
Magnesia	.60
Alkalies	.20
Moisture	.35
Water	12.30
Total	100.35
Total fluxes	2.52

A sample of the second grade of crude kaolin from the Maryland Kaolin Company, at Northeast, Cecil county, was also tested (258, Elkton 4). This differs from the first grade chiefly in having a larger percentage of iron oxide, and consequently the washed clay from it does not burn to as white a color. It is very sandy and when thrown into water falls apart very rapidly.

A sample of the crude material was washed through screens with the following results: Residue on 80-mesh, 5.6%; on 100-mesh, 1.5%; on 150-mesh, 4.5%.

The material therefore contains 88.4% of grains sufficiently fine to pass a 150-mesh sieve. In actual practice, however, this is a much larger proportion than could be floated off to settle in the tanks employed for that purpose.

When burned to cone 4 the material shows a total shrinkage of 5% and is white in color, but above this it begins to develop a yellowish tint, so that it could not be used in the manufacture of good grades of white ware.

It is unaffected at cone 27 in the Deville furnace.

Some good outcrops of kaolin are found in the cut of the Philadelphia, Wilmington and Baltimore Railroad on the property of George

FIG. 1.—MARYLAND CLAY COMPANY'S WASHING PLANT AT NORTHEAST, CECIL COUNTY.

FIG 2.—RESIDUAL FIRE-CLAY, J. SMITH'S PIT, DORSEY, HOWARD COUNTY.

W. Sutton at Perryville. This cut is the first large one on the road southwest of Jackson and at a point about one mile southwest of that station (97, Havre de Grace 9). There is, at this point, at least ten feet of the material exposed, but it has never been exploited to any great extent although a small quantity was shipped some time ago for trial.

The material is covered by six to eight feet of Wicomico formation, but Mr. Sutton claims that in his field on the west side of the track the material was struck at a depth of only five feet.

Samples for testing were taken from the west side of the cut at three different points, representing a distance of at least 200 feet.

The kaolin as mined is light-bluish gray in color and has some limonite stains close to the surface. There is much quartz in the material and about 25% was caught on a 100-mesh sieve in the washing of the clay.

Both the crude and washed kaolin are very refractory, barely showing signs of incipient fusion at cone 27.

In burning, owing to its silicious character, the kaolin shows very little shrinkage. The sample tested burned white at cone 8.

Kaolin is found on the property of Mr. Hooper, a little over ½ mile west of Leslie, Cecil county, and about ⅛ of a mile south of the Baltimore and Ohio Railroad tracks, and near a branch of the high road (263, Elkton 4).

This is a material derived from the decomposition of granite and contains a considerable percentage of coarse quartz grains. It is overlain by 8 feet of sandy material. In washing it 38% of the material was retained on the 100-mesh sieve and 5% on the 150-mesh sieve. The material falls to pieces readily in water and could therefore be washed without much trouble. The washed sample burns to a white color at cone 8, and has a shrinkage at this point of but 4%, the air-shrinkage being 2%. When heated to cone 27 in the Deville furnace, it shows simply the beginning of incipient fusion, while the color is quite white. The tensile strength was extremely low as is the case in all kaolins and did not exceed ten pounds per square inch. This property being located so near to the railroad, should be capable of easy and rapid development.

There is on the same property a considerable outcropping of buff kaolin, the material showing not only in a test pit, but also in the ditches along the roads.

The crude material shows moderate refractoriness, becoming viscous at cone 30, in the Deville furnace.

At Broad Creek, underlying the black Patapsco clay, there is a small outcrop of kaolin somewhat similar in appearance to that found in Sutton's cut near Perryville, but containing a larger quantity of iron stain. It is claimed that a first-class washed product was produced here, but that the operations ceased on account of the material giving out. The kaolin crops out in a pit on the south side of the road and also on the north side of Broad Creek. Overlying it is a hard layer of kaolin which has become cemented together and might perhaps serve as a datum plane in further search for kaolin in this region. At the time the deposit was worked, it is said that the water for the washing operation was obtained from Broad Creek, but it seems doubtful whether this stream would be able to supply enough water for the performance of the work all the year round.

A very white looking kaolin is found on the property of I. R. Dean at the point $\frac{2}{3}$ of a mile northeast of the town of Northeast and on the road to Elkton (96, Elkton 4). There seems to be very little stripping necessary but in places the clay is somewhat buffish in color.

A coarse-grained kaolin is found along the Philadelphia, Wilmington and Baltimore Railroad about one mile southwest of Iron Hill (44, Elkton 6), and has been used for lining cupola furnaces.

Kaolin was also struck on the property of Mr. A. Thiess, at a point two miles due north of Mechanic Valley (285, Elkton 4). The material appears very white in color, and there is practically no striping, at least this was the case in the test pits which had been sunk to prospect the material. Much of the kaolin is very white.

Micaceous clay of a residual nature is found in Atkinson's cut on the Baltimore and Ohio Railroad, two miles west of Leslie, Cecil county (64, Elkton 4). The exact thickness is not known. It is, however, quite refractory, for at cone 27 it shows signs of only incipient fusion.

An abundance of kaolin was found in sinking a well on the property of Frank Weeks, Pleasant Hill, Cecil county (Q, Elkton 2). The material contained an abundance of micaceous scales. At cone 27 it burns white, with the merest trace of yellow, and is but incipiently fused.

At Jackson's Baltimore and Ohio Railroad crossing north of Northeast, kaolin is exposed in a section which involves:

SECTION AT JACKSON, CECIL COUNTY.

		Feet.
	Soil	1–2
Patuxent.	Light-colored sandy clay	12
Algonkian.	Kaolin	5+

Kaolin in other Counties.

A residual greenish fire-clay is found at Cement bridge, south of Joppa, Harford county; it contains numerous quartzose fragments. The material vitrifies at cone 27.

White residual clay of micaceous character is found near Warren, Baltimore county (5773, Baltimore 2-3). This is a trifle less refractory than the preceding.

A deposit of residual clay has been opened up along the Baltimore and Ohio Railroad one mile northeast of Dorsey station, Howard county. It is on the property of Mr. Josephus Smith. There is too much iron in the clay to permit its being called a kaolin. The deposit has been formed from the decay of a feldspathic gneiss containing pegmatite veins. The face of clay, as exposed, is 8 to 12 feet in height, and is overlain by 6 to 8 feet of stratified Patuxent sands and gravels, which are stripped off and sold in part for fire-sand. The entire product is shipped to the Baltimore Retort and Fire-brick Works. The exact thickness of the material is not known, but in places at the base of the bank, bed-rock is seen outcropping. On the opposite side of the railroad to the southwest about $\frac{1}{8}$ mile is another residual fire-clay pit belonging to Mr. A. Hopkins. Residual clay has also been struck in the base of the Baltimore and Ohio Railroad sandpit on the same side of the railroad. The residual clay from Mr. Smith's bank (262, Relay 1) is coarse-grained and contains a number of mica scales. Its chief use is as an anti-shrinkage material in the manufacture of fire-bricks, since when burned to as a high a tempera-

ture as cone 8 its total shrinkage is as low as 5%. The air-shrinkage is 4%, and the quantity of water required to mix it up 25%. As is the case with many coarse-grained, residual mixtures the tensile strength is very low, but in such cases high plasticity and tensile strength are usually supplied by other ingredients of the mixture in which this material is used. The clay burns to a yellowish white color. At cone 2 it is still under 6 in hardness and does not resist scratching with the knife until cone 8 is reached; its fusibility lies above cone 27.

Residual fire-clay is being mined at Harwood (8862, Relay 1), Anne Arundel county. Its refractoriness is good, the clay vitrifying at cone 27.

Residual fire-clay is also found on the property of J. Smith at Harwood station (8787, Relay 1), Anne Arundel county.

Kaolin is found on the Bewley Bros. estate near Branchville, Prince George's county (3836, E. Washington 7). The material would have to be purified by washing, but whether the washed product would be sufficiently white for china manufacture can only be determined by actual test. In its crude condition it is very refractory, however, and shows signs of only incipient fusion when heated to cone 27.

Prospecting for Kaolin in Maryland.

Since the kaolin deposits are almost invariably covered by Patuxent sands or gravels it becomes desirable to find some means of determining the possibility of finding kaolin at any given point of the Coastal Plain region.

Kaolin, on account of its freedom from iron can only result from the decay of a rock free from minerals which have iron in their composition, such as, biotite mica, hornblende, pyroxene or garnet. It has also been stated that the Patuxent sands rested on the crystalline rocks of the Piedmont Plateau. These crystalline rocks consist of granites, gneisses, etc. A valuable clue may therefore be gained from an examination of the character of the rocks along the western edge of the Patuxent belt. If at any point these rocks are dark, thus showing the presence of iron-bearing minerals, it is doubtful if good kaolin will be found under the Patuxent to the southeast of this

SCALE
1:1,250,000. 20 Miles = 1 Inch

0 5 10 20 40 60

A. HOEN & CO. BALTIMORE

area. Thus, in Cecil county considerable kaolin is found, but in Harford county the possibility of finding good kaolin is doubtful.

There must always be a certain amount of uncertainty regarding the depth of the deposit, for the decomposition, or change of the rock into kaolin, seldom extends to the same depth over a large area. Indeed, it may be 35 or 40 feet at one point, and only 6 feet at a distance of 40 feet from the first.

The method of procedure, therefore, is to make a sufficient number of borings or test pits to thoroughly prove the depth of the deposit.

Impure Residual Clays.

In addition to the kaolins and refractory Algonkian clays, which are found underlying the Potomac stratified clays near the northwestern edge of the Coastal Plain, there are a number of residual clays which have been derived from various geological formations, and which are found scattered through the Piedmont region of the State, and they also occur locally in the Appalachian region. These clays are usually more or less ferruginous, and on this account often show bright tints of yellow, brown and red. They may have been derived from granites, gabbros, serpentines, gneisses, shales, limestones, or schists. They vary in their thickness, and except in the case of limestones invariably pass by slow gradation, into the parent rock below.

The distribution of these clays, or rather the areas in which they are likely to be found, can be best discussed by referring briefly to the areal distribution of the rocks which yield them.

The clays obtained from the gabbros and similar basic or dark-colored igneous rocks are usually highly plastic, often deeply ferruginous, and in many cases fine-grained. There are three important areas of gabbro, over which these iron-stained residual materials are likely to be found. These areas, as shown on Plate LVIII, are the Stony Forest area of Harford and Cecil counties; a belt extending from Conowingo, on the Susquehanna river, in a south-southwesterly direction to Baltimore; an irregular area beginning west of Baltimore, and extending as far south as Laurel. These dark ferruginous clays

are used for brick-making at several points, and in some cases they also find employment in the manufacture of pottery. Thus, for example, a ferruginous clay of this type is dug four miles northeast of Catonsville, and is used in the manufacture of flower-pots. It is a material of great plasticity and wonderfully high tensile strength, the latter having ranged from 350 to 410 pounds per square inch. The air-shrinkage is 8%, and at cone 08, 11%. At this temperature it burns bright red.

The granites also yield plastic ferruginous clays, but they are less plastic and less ferruginous usually than those derived from the darker rocks. The granites form extensive areas around Port Deposit, Woodstock, Ellicott City and Guilford.

There are a number of crystalline limestones in Baltimore and Harford counties, but owing to the fact that they are magnesian in their character, they tend to break down to a granular sand, rather than to a plastic clay and therefore are not to be looked upon as a source of clay for brick-making materials. Passing to the westward, however, in Washington county, there is found a broad belt of Shenandoah limestone of Cambro-Silurian age, which extends across the State in a slightly northeast and southwest direction, having a width of about 16 miles. Hagerstown lies slightly to the west of the center-line of this belt. In this area there is an abundance of residual brick-clay derived from the weathering of the limestone.

Closely associated with the Shenandoah limestone is the Martinsburg shale, which is also worked to a considerable extent in places. Farther east the residual clay derived from the Shenandoah limestone is also dug in the vicinity of Frederick, where it makes an excellent hard, red brick.

Residual clays of impure character may also be sought for in a belt extending across the State in a northeast-southwest direction, from between Seneca and Great Falls on the Potomac river up to Manchester and Parkton, near the northern border of the State. This area is underlain by argillaceous rocks whose decomposition may furnish brick clays.

The following table shows the composition of residual clays from different localities:

Analyses of Residual Clays.

State and County.	Town.	Material.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water. Combined	Water. Free	Miscel.	Firm Names, Authority or Analyst.
ALABAMA:												
Calhoun.........	Morrisville.	From Knoxville limestone.	55.42	22.17	8.3	.15	1.45	2.49	9.86			
ARKANSAS:	....	From St. Clair limestone.	33.55	30.18	1.98	3.89	.26	1.57	10.72		P_2O_5 2.53	From Arkansas Geological Survey Report on Manganese.
GEORGIA:												
Bartow..........	Cartersville.	....	58.63	20.47	8.58	tr.	1.42	4.00	7.26			Georgia Geol. Survey, 1893.
Polk............	Rockmart.	....	61.66	19.64	7.54	tr.	tr.	2.32	....			Ibid.
KENTUCKY:												
Graves..........	....	From chert.	76.78	14.74	1.64	tr.	.389	1.557	48.94			Kentucky Geological Survey Chemical Report A pt. 3.
MISSOURI:												
Iron.............	R.R. cut Tiptop.	....	90.05	4.63	2.31	tr.	tr.	....	2.72			Missouri Geological Survey XI p. 564.
Lincoln	Morris shaft.	... .	72.35	15.86	2.25	1.09	1.48	....	3.05	1.46	Loss 2.46	
NORTH CAROLINA:												
Wake............	Cary.	....	54.54	26.43	9.04	....	....	....	9.87			
PENNSYLVANIA:												
Lehigh	Fogelsville.	From slate.	72.164	21.764	.99	.224	.698	5.139	4.758			Pennsylvania Geological Survey D. p. 13.
WISCONSIN:												
Wood..........	Grand Rapids.	....	70.83	18.98	1.24	.24	.02	2.59	5.45		CO_2 1.02	Wisconsin A. C. Sci. 1870-1876.

Resume.

BRICK-CLAYS.

Clays suitable for the manufacture of common brick are so numerous at all localities that it is scarcely necessary to make any extended search for them since they are easily found. In Maryland common brick are made from three types of deposit, namely: the Coastal Plain sedimentary clays; residual clays of the Piedmont region, and the shaly deposits of the Appalachian region.

In the Coastal Plain region clays suitable for the manufacture of common brick are to be found everywhere. The Columbia loams of Pleistocene age form a mantle over most of the surface which extends from the southeastern to the northwestern border of the Coastal Plain, and from the northeastern end of it in Cecil county to the southwestern end of it at Washington. These Columbia loams, on account of their grittiness and ferruginous character, are excellently adapted for the manufacture of common brick and are widely used in the vicinity of Baltimore. They have sufficient iron to burn to a good red color, enough fine particles to insure proper plasticity, and enough grit to prevent excessive shrinkage in burning. At times they become more or less loessoid in their character, but this would not in any way prevent their use in brick manufacture since the loess, which is the great brick-making material of the Western States, burns into an excellent red brick. Next to the Columbia, the Tertiary is a material of considerable value and is quite as well suited for the manufacture of pressed as of common brick. It yields the red clay so abundant around Upper Marlboro. Its extent is, however, not equal to that of the clay formations underlying it geologically.

The Raritan formation is perhaps unique in yielding a greater proportion of buff-burning clays than the Arundel or Patapsco which follow it. Red-burning ones have also occurred. Its greatest development is to be looked for in Anne Arundel county. A large deposit of it is now being worked south of Harman, on the Pennsylvania Railroad. Additional outcrops are found along the Severn river, and some of the clays in this locality, as mentioned under the discussion of the Raritan materials, burn to a buff color.

FIG. 1.—GENERAL VIEW OF CONOCOCHEAGUE BRICK AND TILE COMPANY'S WORKS, WILLIAMSPORT, WASHINGTON COUNTY.

FIG. 2.—PIT OF WASHINGTON HYDRAULIC-PRESSED BRICK COMPANY, HARMAN, ANNE ARUNDEL COUNTY.

The Patapsco formation, with its enormous amount of variegated so-called terra cotta clays, is almost co-equal in extent with the Columbia as far as its northeast and southwest distribution is concerned. It is more plastic as a general rule than the Columbia clay and forms much thicker deposits so that the occurrences of it are better adapted towards supplying a large clay-working plant and also for the manufacture of the denser product. Its greater plasticity would no doubt make it available for the manufacture of stiff-mud brick while the Columbia clays might sometimes be too gritty for this purpose. These enormous deposits of variegated Patapsco are often located close to the water or along the railroad so that in either case the shipping facilities are excellent.

Underlying the Patapsco stratigraphically and usually lying to the northwest of it in its areal distribution come the Arundel deposits with their enormous supplies of iron-ore clays. These deposits, which occur at many points, notably in the vicinity of Muirkirk, Soper Hall, Hanover, Relay, Baltimore, Monumental and Joppa, have been found to be excellently adapted for making not only common brick but also pressed brick. They are moderately silicious in their nature, highly plastic and have sufficient iron to burn to a good red color. At some localities it is found that these Arundel clays are comparatively free from iron so that they burn buff instead of red and lend themselves well to the production of terra cotta and roofing-tile.

The Patuxent is of comparatively little value as a brick-making material, the deposits in most cases being sandy or in the nature of refractory clays which are of too high grade to be used for common brick.

Many localities have been referred to in the detailed account of the clays found in the post-paleozoic formations, but since the references are scattered through a number of pages it has been thought best to give lists of the localities for the different kinds of clay, arranged according to counties, and under these according to formations. These tables show at once under which geologic group any

deposit is described. It is to be understood that every deposit in any one county is not included in the list, but simply the more important ones which it has been possible to examine.

Localities from which Brick-clays are mentioned.

Cecil County.

PLEISTOCENE.—Underlying the terrace east of the town of Elkton.

In the bluffs along the shore at the foot of Bull Mountain on the westerly side of Elk Neck (239, Elkton 7).

On Wilson's Beach, Elk Neck.

On Stump Point (5811, Havre de Grace 9).

In the Pennsylvania Railroad cut at Perryville.

RARITAN.—Along the eastern shore of Northeast River, northeast of Bull Mountain (30, Elkton 7).

PATAPSCO.—Two miles south of Northeast, on the road to Elk Neck (260, Elkton 7).

On the Old Neck Road about three miles south of Elkton (90, Elkton 8).

In Thompson's gulley (91, Elkton 8).

On Locust Point (8828, Havre de Grace 9).

At Hance Point (24, Elkton 7).

Three-quarters mile west of north from Elk Neck (85, Elkton 7).

Near the eastern shore of the Northeast River, 2½ miles south of Northeast (244, Elkton 7).

On Welch Point (34, Elkton 8).

Along the shore from Carpenter Point, northwest for ¾ of a mile.

At Charlestown station on the Philadelphia, Wilmington and Baltimore Railroad (16, Elkton 7).

The variegated Patapsco clays are especially well developed at the following localities:

In the Deep Cut east of Principio station on the Philadelphia, Wilmington and Baltimore Railroad (255, Havre de Grace 9).

One-half mile east of Red Point near Elk Neck (84, Elkton 7).

Three-quarters mile north of Elk Neck village.

At the north end of Bull Mountain (88, Elkton 7).

FIG. 1.—THE BURNS AND RUSSELL COMPANY'S TERRA COTTA WORKS, BALTIMORE.

FIG. 2.—MOLDING ROOM, THE BURNS AND RUSSELL COMPANY'S TERRA COTTA WORKS.

In the hill west of Charlestown (17, Elkton 7).

Between Elkton and Eder, near the branch road to Childs (10, Elkton 5).

In the cut of the abandoned Newcastle and Frenchtown Railroad (40, Elkton 9).

Along the Philadelphia turnpike at Grays Hill (43, Elkton 6).

In the river-bluff at Shadow Hall Point, 2 miles due south of Principio Furnace (50, Havre de Grace 9).

In Foys Cut on the Baltimore and Ohio Railroad (15, Havre de Grace 6).

One and a half miles west of Northeast station (13, Elkton 4).

Three-quarters mile east of Elk Neck (31, Elkton 7).

Along the shore of Northeast River, $\frac{3}{4}$ mile south of Hance Point (25, Elkton 7).

Near Bacon Hill station on the Philadelphia, Wilmington and Baltimore Railroad.

Harford County.

Pleistocene.—South of Havre de Grace on the Davis estate (8829, Havre de Grace, 8).

Along the shore from Stone Point to Bush River.

Patapsco.—Many scattered occurrences of the variegated Patapsco.

North of Otter Point Creek on the Buena Vista farm.

On Maxwell Point.

On the hill between Stepny P. O. and Cranberry Run.

Arundel.—Near the head of Bird River, at Prospect Hill near Joppa.

South of Joppa and near Clayton station.

Near the head of Otter Point Creek (151, 152 Gunpowder 3).

East of Abingdon.

West of Belcamp.

Baltimore County.

Pleistocene.—Many Columbia clays are found up to 20 feet above sea-level around Baltimore, also in the districts northeast of Sparrows Point.

Patapsco.—At Cromwell Bros.' brick yard at Rossville (8852, Gunpowder 4).

Arundel.—North of Curtis Bay Junction and near the Washington road (250, Baltimore 8).

Smith and Schwartz' brick yard (8950, Baltimore 8).

On the point southeast of Smith Cove (10, Baltimore 8).

Monumental, south of Baltimore.

Busey's brick yard, 1 mile south of Mt. Winans (57, Baltimore 8).

Pitcher and Creager's clay pits, Baltimore (8321, Baltimore 8).

Classen's brick-yard, Baltimore (8958, Baltimore 8).

Anne Arundel County.

Pleistocene.—In the old brick-clay pits near Curtis Bay (8783, Relay 2).

South of Bodkin Point (266, North Point 4).

Raritan.—On property of Wm. Jones in Swan Cove on the Magothy River (265, Relay 9).

At the site of the old Riverside Brick Works on Severn River (297, Relay 9).

One mile south of Glenburnie.

One-half mile south of Harman station, on the Pennsylvania Railroad (175, Relay 4).

Patapsco.—Very little. .

Arundel.—Mr. Reynolds iron mine, Piney Run, 1⅔ miles south of Hanover (Relay 1).

One and a half miles east of Laurel.

Around Patuxent station.

In the ore mines at Jessups (Laurel 6), Annapolis Junction (Laurel 6) and Dorsey (Relay 1).

Howard County.

Arundel.—At the Timberneck mine near Dorsey (Relay 1).

The Diven estate iron mine at California between Contee and Muirkirk (8200, Laurel 8).

The Ashland mine 1½ miles northeast of Jessups (8861, Laurel 6).

BALTIMORE TERRA COTTA WORKS.

PATUXENT.—In the bank of Deep Run on the H. Brown estate, Timberneck, near Hanover (8962, Relay 1).

Prince George's County.

EOCENE.—At Upper Marlboro.

PATAPSCO.—Southeast of Bowie.

At Horsepen Run.

On the public road at Broad Creek Hill south of New Glatz.

In the Baltimore and Potomac cut 1 mile northeast of Bowie.

On the Waverly estate 1 mile east of College station road cut (5834, East Washington 2).

ARUNDEL.—At many points in the ore mines, notably on the Peterson estate west of Contee and at the iron mine east of Annapolis Junction (179, Laurel 6).

PATUXENT.—On Bewley Brothers estate at Branchville (5851, Laurel 7).

Kent County.

RARITAN.—Worton Point (Betterton 7).

The residual clays of the Piedmont region are derived from either gneisses, granites, limestones or schists, as a general rule, and in almost every case are quite ferruginous so that they not only burn to a deep red product but may do so at a comparatively low temperature. Those which are derived from a basic igneous rock, such as gabbro or peridotite, usually have a very high plasticity and consequently will show a high shrinkage in burning. Owing to their high plasticity, however, they should permit of the admixture of considerable sand, although the manufacturer may have some difficulty in thoroughly incorporating the material with the clay. The residual clays are likely to be variable in their depth owing to the uneven surface of the underlying rock, and consequently they may vary anywhere from 3 or 4 to 25 or more feet in thickness.

The shales suitable for brick-making are to be found either in the Devonian or Carboniferous, although up to the present time only the former have been used. With an increase in demand for bricks

in the counties of the Appalachian region the Carboniferous shales will no doubt spring into prominence and be opened at a number of points.

Baltimore is the great center of the brick-making industry in Maryland, and in and around the city there are many common-brick plants using the deposits of Arundel and Columbia clays.

As the growth of the city has progressed, the yards in many instances have been moved further out. In the last fifty years there has been comparatively little change in the common-brick industry around Baltimore, but in July, 1899, a company, known as the Baltimore Brick Company, was organized, which bought up most of the yards in Baltimore and its vicinity, including the following firms:

Baltimore High Grade Brick Co.,	A. & F. Wehr,
Weaver & Harman,	Maryland Brick Co.,
Pitcher & Creager Brick Co.,	Wm. H. Perot,
Jas. R. Busey & Son,	Smith & Schwartz Brick Co.
H. W. Classen & Co.,	Cromwell Bros.,
John A. Knecht & Sons,	Druid Brick Co.,
Dan'l Donnelly & Sons,	John A. Allers & Son.

The capacity of this company's works is about 150,000,000 brick per annum. The methods of manufacture in use at their yards and those of the independent firms are essentially the same. The bricks are usually molded on Henry Martin soft-mud machines, or Chamber's stiff-mud machines, while burning is carried on in Morrison Patent Kilns or the old scove kiln. Dry press, speckled and ornamental bricks are made at one of the yards of the Baltimore Brick Company.

Aside from Baltimore there are few localities in the State, at which we find several brick plants, although single factories are to be found in many localities all over the State. Thus at Hagerstown there are several yards engaged in the manufacture of common brick. They all use the residual limestone clays so abundantly developed in that vicinity. The brick are molded either by hand or in soft-mud machines.

At Williamsport, six miles west of Hagerstown, a clay is being used which is a mixture of residual material and stream deposit.

MARYLAND PENITENTIARY SHOWING ROOF COVERED WITH MARYLAND ROOFING TILE.

The works of the Conococheague Brick and Earthenware Company which use this material are located ¼ mile north of Williamsport, and adjoining the yard are about 34 acres of clay and shale land. The bricks are molded on a Hercules soft-mud machine, and when to be sold for front brick are repressed on a Steele repressing machine. The drying is done on pallets and the burning in Morrison kilns, yielding an excellent red product.

The following tests give the character of the raw materials and product. The former were by the writer and the latter by Maj. J. W. Reilly at the Watertown, Massachusetts, Arsenal:

SAMPLE NO. 1 DARK RED CLAY.

At 2,000° Fahr. burns to a bright red hard body. Briquettes made from the wet clay had when air-dried a tensile strength of 50 lbs. per square inch. The chemical analysis showed:

Silica	67.50
Lime	.45
Water	5.90
Alumina	17.20
Magnesia	.33
Moisture	.20
Ferric oxide	6.70
Alkalies	1.76
Total	100.04

SAMPLE NO. 2, LIGHT RED CLAY WITH YELLOW TINT.

Very similar to analysis No. 1, less in lime, which is only....... .22

SAMPLE NO. 3, YELLOW CLAY.

Analysis similar to Nos. 1 and 2.

SAMPLE NO. 4. LIGHT GRAY CLAY.

Analysis at 2100° Fahr. burns to hard light red and at 2200° Fahr. becomes dense and nearly vitrified. Air-dried briquettes had an average tensile strength of 140 lbs. per square inch. Chemical analysis:

Silica	61.30
Lime	.70
Water	8.00
Alumina	22.30
Magnesia	.86
Ferric oxide	3.80
Alkalies	2.10
Total	99.06

Owing to its plasticity, smoothness and good color when burned, this clay should lend itself well to the manufacture of earthenware and common stoneware.

Tests made of bricks of the "Conococheague" Brick and Earthenware Company, of Williamsport, Maryland, March 22, 1898. Tested flatwise gave the following results:

Common red bricks, ultimate strength 3966 lbs. per square inch. Red Front Bricks, ultimate strength 6470 lbs. Red Pressed Bricks, ultimate strength per square inch 4172 lbs. Dark Red Pressed, ultimate strength 4391 lbs. per square inch.

At Frederick there are also several brick yards, but here the material used is a residual shale, which burns to an excellent hard red brick.

It is remarkable that with the abundance of good shale to be found in the western part of the State, there is only one plant utilizing the material. This is the Queen City Brick and Tile Company (Plate LV, Figs. 1 and 2), whose works are located along the Baltimore and Ohio Railroad, one mile southeast of Cumberland.

The material used is the Jennings shale, a subdivision of the Devonian, occurring in great thickness in Garrett and Allegany counties, as shown on the geological maps of these counties. The shale bank is 12 to 15 feet high, and capped with 3 to 4 feet of loose sand and gravel. The upper layers of the bank are much softer on account of being slightly weathered, while the lower ones are quite hard. All of the shale will, however, slake quite readily on exposure to the air. While the upper layers are more plastic it is claimed the lower ones burn to a better red color. In making bricks a mixture from top to bottom of the bank is used, with the exception of a few sandstone layers which are thrown out. The shale is ground in a nine-foot dry-pan, put through a Raymond pugmill, and molded in an auger side-cut machine. The bricks are dried in tunnels and burned in circular down-draft kilns of Yates type or in Swift kilns with coking hearth.

The following dimensions will serve to indicate the amount of shrinkage which the shale undergoes in drying and burning:

Freshly molded brick	$8\frac{3}{4} \times 2\frac{1}{2} \times 4\frac{5}{32}''$
Repressed brick	$8\frac{9}{16} \times 2\frac{9}{16} \times 4\frac{1}{4}''$
Burned brick	$8\frac{1}{8} \times 2\frac{1}{2} \times 3\frac{3}{4}''$

The product has an excellent red color and low absorption. It is sold for paving and building purposes.

FIG. 1.—KILN SHED, UNION MINING COMPANY, MOUNT SAVAGE.

FIG. 2.—HEAPS OF CLAY WEATHERING AT MINES OF SAVAGE MOUNTAIN FIRE BRICK WORKS.

TERRA COTTA CLAYS.

The terra cotta industry of Maryland is comparatively little developed and yet what has been done is sufficient to show that suitable materials for this purpose are not lacking within the limits of the State.

The three kinds of clay which have chiefly been employed for this purpose thus far are buff-burning Arundel clays, sandy Patuxent clays, and variegated Patuxent clays. The first type is well developed in Anne Arundel county, although it may be sometimes difficult to tell from a field inspection whether the Arundel clay will burn to a red or buff color. The buff-burning Raritan clays, such as those found south of Harmans, or along Horsepen Run in Prince George's county, are also worth the attention of terra cotta makers. The sandy Patuxent clays are to be found at a number of points in the belt underlain by Patuxent deposits and also around the upper end of the Severn river. The variegated Patuxent which is used at the terra cotta works at Terracotta near Washington, D. C., is a type of clay which occurs in the form of lenses in the Patuxent at a number of different localities. In general appearance and plasticity this clay is not at all unlike the variegated Patapsco which is far more abundant.

The factory of The Burns and Russell Company, located on the Columbia road at the southern edge of Baltimore, is the only one at present engaged in the manufacture of terra cotta and roofing-tile. Their results are most interesting as showing what can be done with the Arundel and Patapsco material which is their chief source of supply. From this they produce an excellent grade of terra cotta and also roofing-tile, the latter being specially unique, since they are among the few glazed ones made in the United States. The general body of the clay is buff, but the glaze is sometimes colorless and transparent, at other times brightly colored, and thus capable of producing a very effective roof.

Among the buildings covered with these may be mentioned the Maryland Penitentiary and the City College of Baltimore, the First Baptist Church, and the residence of C. P. Huntington, New York City, and W. C. Whitney's residence at Rosslyn, Long Island.

The manufacture of roofing-tile was at one time attempted at Glenburnie, but was subsequently given up.

SEWER-PIPE CLAYS.

There is but one factory in the State which is engaged in the manufacture of sewer-pipe at the present time and the raw materials used for this purpose are drawn entirely from the Arundel, although it is probable that equally good clays could be obtained from the Pleistocene of Anne Arundel and the Patapsco of Cecil counties.

The small amount of sewer-pipe made in Maryland is due rather to trade conditions than lack of clays, for both the Arundel and Patapsco formations yield materials of considerable plasticity.

These clays are used at the Baltimore Terra Cotta Works, corner Jackson and Clement Streets, Baltimore. The Arundel clays are dug on the north side of the yard, and show two distinct varieties, viz.: an upper bed of drab-colored, fine-grained, plastic clay, underlain by a less plastic slate-colored, silicious clay. These two are mixed together with sand for the sewer-pipes and flue-linings. The pipes are dipped in Albany slip instead of being salt glazed, and are then burned in a down-draft circular kiln, using coal fuel.

FIRE-CLAYS.

The refractory clays found in the State are obtained either from the Coastal Plain formations or from the Carboniferous of the Appalachian Region. The Carboniferous fire-clays of Maryland have long been well-known, the deposits having been worked since 1841. They are found as stated in another part of the report in the Pottsville member of the Carboniferous and the outcrops are being worked on Savage Mountain. From these two forms of fire-clay are obtained: a plastic clay or shale and flint clay. Both of them are highly refractory in their character. In the Coastal Plain region fire-clays are obtained from Patapsco and Raritan and Patuxent and Algonkian. The first three of these contain many lenses or extensive beds of white to yellowish-white clays which frequently show a high resistance to fire and can be heated up to the fusing point of cone 27 with-

FIG. 1.—MOLDING DEPARTMENT, UNION MINING COMPANY, MOUNT SAVAGE.

FIG. 2.—MOLDING FIRE-BRICK.

out, in many cases, becoming vitrified. A number of occurrences of refractory clays of Potomac age have already been mentioned in the preceding pages but for convenience and cross-reference these are listed below.

Cecil County.

RARITAN.—At McKinneytown, 3 miles south of Northeast (290, Elkton 7).

One mile east of Piney Creek on the old road to Elkton.

At the base of Maulden Mountain in "White Banks."

On C. W. Purner estate on Elk Neck, in the north and south banks of the mill-dam at Piney Creek (8771, Elkton 7).

In the Baltimore and Ohio Railroad cut at Foys Hill (5729, Havre de Grace 6).

At Rogues Harbor (X, Cecilton 1).

One and one half miles northeast of Elkton (43, Elkton 6).

PATAPSCO.—On the property of C. Simpress one-half mile south of Eder (288, Elkton 5).

On Bacon Hill (8775, Elkton 5).

On the land of H. L. Gaw below Hance Point.

At Broad Creek (265, Elkton 4).

On the Neil property at Northeast (5796, Elkton 4).

On the Clay Fall estate (52, Havre de Grace 9).

At Red Hill (5817, Elkton 6).

Harford County.

RARITAN.—Near Abingdon.

On hill above Water's Mine one mile south of Clayton station on the Baltimore and Ohio Railroad (9034, Gunpowder 3).

PATAPSCO.—Below the public landing on Swan Creek (176, Betterton 2).

Around the head of Bush River, especially on the eastern shore, at the mouth of Church Creek.

PATUXENT.—In the Otter Point cut near Sewall on the Baltimore and Ohio Railroad (5750, Gunpowder 3).

On Gunpowder River above the north end of the Philadelphia, Wilmington and Baltimore Railroad bridge (178, Gunpowder 5).

At a point below the Otter Point Landing (180, Gunpowder 3).

At Jackson Hill, 1½ miles northwest of Aberdeen.

Baltimore County.

PATAPSCO.—At Knecht's brick yard, Columbia Avenue, Baltimore (8816, Baltimore 8).

ARUNDEL.—At Locust Point (232, Baltimore 8), near Fort McHenry.

Anne Arundel County.

RARITAN.—Along the Severn River opposite Proctor's Park.

In Brown's glass-sand pits, near the head of Severn River (246, Relay 9).

In Baldwin's glass-sand pits near the head of Severn River (238, Relay 8).

On the Dorsey estate, near the line of the projected Drum Point Railway (Relay 8).

On H. T. Wade estate, 2½ miles south of Glenburnie (8843, Relay 5).

At Round Bay near Rocky Point (Relay 9).

On the Spear estate, Earleigh Heights (8851, Relay 8).

PATAPSCO.—Near Walnut Point on Curtis Creek (8836, Relay 3).

One-half mile south of Welham station on the Baltimore and Annapolis Short Line (10, Relay 2).

On the property of J. C. Knecht, Stone House Cove (5780, Relay 3).

PATUXENT.—On Deep Run, on the H. Brown estate at Timberneck (8960, Relay 1).

On the Randall estate (8846, Relay 1).

Howard County.

On the Hartsock estate near Jessups on Baltimore and Ohio Railroad (8777, Laurel 6).

In the Baltimore and Ohio Railroad cut near Savage (8320, Laurel 6).

FIG. 1.—MOLDS FOR GAS-RETORTS, BALTIMORE RETORT AND FIRE-BRICK COMPANY.

FIG. 2.—RETORTS PLACED IN KILN FOR BURNING.

Prince George's County.

RARITAN.—On Horsepen Run (East Washington 3).

PATAPSCO.—On Bewley Bros. estate at Branchville (5853, Laurel 7).

Kent County.

RARITAN.—At Betterton (8694, Betterton 6).

The Algonkian fire-clays which are residual in their nature are opened up at three different points, namely, around Northeast, Cecil county, at Dorsey, Howard county, and on the western edge of Baltimore.

In Plate LXVIII are shown a number of cones of Maryland clays which have been heated to cone 27 in the Deville furnace.

Fire-brick and Stove-brick.

The refractory-ware industry of Maryland is indeed one of the most important branches of the clay-working industry found in the State.

The largest fire-brick works, and one whose product has won a wide reputation is that of the Union Mining Company, at Mount Savage, Allegany county. This plant was opened in 1841 and has been in operation ever since. The clays used were discovered in 1837 and at that time were employed in lining two blast furnaces there in use by the Maryland and New York Coal and Iron Company.

The clays are obtained from Savage Mountain, 2½ miles west of Mount Savage. Two types are obtained, viz.: a flint clay and plastic shale clay. They are run down to the works in tram cars and piled up to weather until used. While the chief product of the works is fire-brick, still other shapes are also made. The clays are ground and mixed in a nine-foot dry-pan, one such pan grinding enough clay in 6 hours for 9000 brick. The molding is done by hand, in three division molds, one molder and two boys molding 3000 brick per day.

The drying is done on brick floors 97 x 130 feet and heated by flues passing underneath. After drying for several hours the bricks are taken up and repressed. It takes about 3½ tons of clay to make 1000 bricks.

30

Many bricks are made for reheating, puddling, and similar furnaces. Where the brick is to be subjected to considerable abrasive action a very large percentage of the plastic clay is used, but where high refractoriness is called for a larger proportion of flint clay goes into its composition.

A special feature of this factory is its continuous kilns, heated by producer gas. There are two of these kilns, each capable of holding 315,000 nine-inch bricks. The method of burning with producer gas at this works has been described by R. S. Cook.[1]

Another factory, viz.: the Savage Mountain Fire Brick Works is located at Frostburg, Maryland.

The mines, which are on leased property, are located 2½ miles northwest of Frostburg near the summit of Savage Mountain.

The bed has a dip of about 12 degrees, and is mined by drifts which run into the hill a distance of 300 to 500 feet. The clay is 6 to 8 feet thick, and overlain by the Mount Savage coal. While the plastic clay is usually at the top of the bed and the flint below, still the reverse is at times true. The flint clay is shipped directly to the works, but the plastic clay is allowed to weather for some time at the mine. A track nearly a mile long leads part way down the mountain to the clay-bins. The loaded cars are run down by gravity, and the emptied ones hauled back by horses. The clay is dumped from the bins into carts and hauled to the works at Frostburg.

A mixture of flint and plastic clay is used. The tempering is done in wet-pans, and the molding and repressing by hand, the works having a capacity of about 9000 bricks per day. There are four rectangular updraft kilns.

A third plant is that of Gardner Bros. at Ellerslie. The mines are located to the westward near the top of Alleghany Mountain, and are connected with the works by means of a gravity-plane and tramroad. The company has two openings, most of the hard or flint clay coming from the one on the Maryland side of the border and the plastic soft clay from the drift on the Pennsylvania side of the border. The clay, which is considered by many to be at a lower horizon than the Mount Savage clay, varies in thickness from 8 to 14 feet. The

[1] Trans. Amer. Inst. Mining Engineers, xiv., 1886, p. 698.

FIG. 1.—KILN, BALTIMORE RETORT AND FIRE-BRICK WORKS.

FIG. 2.—INTERIOR OF KILN OF FIRE-BRICK, SAME WORKS.

clays are not weathered, but are charged directly into the dry-pan, and from this to a wet-pan. The yard has three rectangular and two round kilns, the former being down-draft, having a bag wall in each corner. This necessitates fires being also built in the doorways.

The Baltimore Retort and Fire Brick Company is located corner Hull and Nicholson Streets, Baltimore, Maryland. Their product consists of clay retorts, blocks and tiles, as well as fire-bricks. The clays used include a residual clay from Dorsey, a plastic Arundel clay from the same locality, and fine sand. The mixture of clays is tempered by soaking in a pit and the bricks are molded by hand and repressed. The drying is done on flue-heated floors. Many gas retorts are also made at these works, and also chimney tops. The latter are, however, made from a red-burning clay (Plate LXV, Figs. 1 and 2). The kilns are rectangular, down-draft ones, and the waste heat from them is used to heat the drying floors.

Many stove-brick and stove-linings are annually produced in the vicinity of Northeast, Cecil county. Since these are not subjected to a very high temperature when in use the clay required is not necessarily of the most refractory character.

One of these works at Northeast is that of the Wakefield Fire Brick Company. The company owns three acres of clay land and leases a fourth. From these properties several different types of clay are obtained, and by uniting them in the proper proportions a mixture of the right shrinkage is obtained. The brick are all molded by hand and burned in two down-draft kilns.

Stove-linings are also manufactured by Wm. L. Cowden at Northeast. The materials used are a red clay from the Neil property, plastic clay from the Thomas farm, and a residual refractory clay from Grey's Ferry near Philadelphia.

With the location of these works near points of shipment, there seems no reason why the Maryland stove-brick industry should not expand in the future.

Enameled Brick.

Maryland possesses one of the few enameled brick works located in the United States, viz., the factory of A. Ramsay at Mount Savage, Allegany county.

The clays used are a mixture of shale and flint fire-clay from the mines on Savage Mountain. The factory, which was started in 1896, has a capacity of 1,200,000 bricks per year. They are molded on stiff-mud machines, dried on brick floors, and burned in rectangular, down-draft kilns, of which there are four (Plate LXVII).

The excellent quality of the product is widely known, and a large number of the bricks have been ordered for the new rapid transit tunnel, being constructed in New York City. The bricks have also been used in the construction of the new Post-office at Buffalo, New York; the Post-office at Back Bay, Boston; the South Boston electric plant; the Union Depot at Boston and the Printing House at Washington.

POTTERY CLAYS.

Under this heading must be included materials showing a wide range of composition. The kaolins, such as would be used in the manufacture of white earthenware and porcelain are to be found chiefly in Cecil county, and have there been opened up and prospected at a number of points. They represent an extension of the kaolin belt which is so abundantly worked in Delaware.

The localities which have been noted (see Algonkian Residual Clays) are as follows:

Cecil County.

One mile southwest of Northeast.

On cut of Baltimore and Ohio Railroad 1 mile southwest of Jackson (97, Havre de Grace 9).

On G. Hooper's property one-half mile west of Leslie.

At Broad Creek.

On J. R. Dean's property, $\frac{2}{3}$ mile northeast of Northeast (96, Elkton 4).

One mile southwest of Iron Hill on Philadelphia, Wilmington and Baltimore Railroad (44, Elkton 6).

On land of A. Thies, 2 miles north of Mechanic Valley (285, Elkton 4).

In Atkinson cut of Baltimore and Ohio Railroad 2 miles west of Leslie (64, Elkton 4).

On land of F. Weeks, Pleasant Hill (Q, Elkton 2).

FIG. 1.—MOLDING ENAMELED-BRICKS, MOUNT SAVAGE.

FIG. 2.—DRYING ROOM OF ENAMELED-BRICK WORKS, MOUNT SAVAGE.

Harford County.

At Cement Bridge south of Joppa.

Baltimore County.

At Warren (5773, Baltimore 2-3).

Howard County.

At Harwood station on Baltimore and Potomac Railroad (8962, Relay 1).

Near Dorsey on land of J. Smith.

Clays suitable for the manufacture of stoneware are to be found at many points in the Patapsco, especially in Cecil county, and tests of a number of these are given in another part of the report. At the base of the Patapsco, especially in the county mentioned, there is often a bed of bluish-gray, very plastic stoneware clay which is frequently as much as 8 to 10 feet in thickness. Aside from these Cecil county stoneware clays the most important perhaps are those outcropping along the shore from Bodkin Point southward. Clays suitable for the manufacture of yellow ware are to be found at a number of points in the Arundel deposits and also in the Columbia, both of these formations being extensively drawn upon by the yellow and Rockingham ware manufacturers of Baltimore. Clays for the manufacture of common red earthenware are abundant and are obtained from the Columbia, Arundel and Patapsco formations of the Coastal Plain, and from the residual clays of the Piedmont Plateau, northeast of Catonsville, or of the eastern Appalachian Region around Hagerstown.

The localities which have been mentioned in the detailed descriptions of the Pleistocene and Potomac formations are given below.

Cecil County.

RARITAN.—One mile northeast of Elk Neck Village on Piney Creek (32, Elkton 7).

PATAPSCO.—On property of W. Grosh on Bacon Hill road 3½ miles east of Northeast (234, Elkton 5).

At head of Beach channel on property of J. F. Simpcoe, near Carpenter Point (245, Havre de Grace 9).

On property of Chas. Simpress, ½ mile south of Eder (240, 288, 292, Elkton 5).

On highway ½ to 1 mile west of Bacon Hill (20, 21, Elkton 5) and also on Caleb Grant property nearby.

On Plum Creek (8773, Elkton 8).

On Thos. Reed estate 2¼ miles southwest of Elkton (36b, Elkton 5).

At northern base of Bull Mountain on Elk Neck (88, Elkton 7).

On land of Capt. Fletcher Wilson, ½ mile below Upper White Bank.

On property of Chas. Simpress, along eastern shore of Northeast River, and southeast of Charlestown (253, Elkton 7).

Three and one-quarter miles due southwest of Elkton station (35, Elkton 8).

On Oldfield Point (37, Elkton 8).

One-half mile south of Northeast (18, Elkton 4).

Patuxent.—On J. H. Ford property, Northeast (264, Elkton 4).

Harford County.

Arundel.—On south shore of Otter Point Creek opposite Light's landing (150, Gunpowder 3).

At John Everett Iron Mine (5777, Gunpowder 2).

Near the Light Mine, Joppa.

Baltimore County.

Arundel.—On Ned Savage estate, Spring Gardens (8877, Baltimore 8).

Anne Arundel County.

Pleistocene.—Along the shore of Chesapeake Bay south of Bodkin Point (North Point 4).

Raritan.—At site of former Riverside Brick Works (297, Relay 9).

On Dorsey estate at head of Severn River (8857, Relay 7).

CONES OF MARYLAND CLAYS FROM DIFFERENT LOCALITIES WHICH HAVE BEEN HEATED TO CONE 27 (3038° FAHR.) IN THE DEVILLE FURNACE.

Arundel.—On the land of Charles Needer, 1 mile northeast of Patapsco station on Pennsylvania Railroad (8819, Laurel 4).

Howard County.

Arundel.—At Hobbs iron mine, Hanover (8243, Relay 1).

Prince George's County.

Patuxent.—On Bewley Bros. estate near Branchville (3836, East Washington 7).

The Pottery Industry.

As will be seen by reference to the statistical table given in preceding pages of this report, the manufacture of pottery forms a most important branch of the Maryland clay-working industry. Furthermore, the products include all grades, from the common red earthenware to high-grade white earthenware. At Baltimore there are two important works making whiteware. One of these is the Chesapeake Pottery.[1] "Although among the youngest of the American potteries, has achieved a high reputation for the variety of excellent and novel bodies and glazes it has produced, and has won still greater distinction by the beauty and originality of its designs, both in form and decoration. The works were started in 1881 by Messrs. D. F. Haynes and Company, and were continued without change until 1887, when the style was altered to the Chesapeake Pottery Company, and in 1890 Messrs. Haynes, Bennett and Company assumed control and are still operating the pottery with marked success. Mr. David Francis Haynes, the senior partner, has stood at the head of the business since its inception. On purchasing the Chesapeake Pottery property, Mr. Haynes entered into the production of a variety of wares, being greatly aided by the knowledge gained in the jobbing trade of the productions of the Old World and the wants and tastes of the American.

"When this factory was started majolica ware was in great demand. Its first product was called 'Clifton' ware, and belonged to the majolica family, but was superior in body and glaze and was

[1] For historical data in this chapter, credit is due E. A. Barber, Pottery and Porcelain of the United States.

pronounced by judges equal to the famous Wedgwood ware of that grade. Following this came the 'Avalon' ware, which was of a fine body, of ivory tint and soft rich glaze, ornamented with sprays of flowers in relief which were touched with color and gold, making a pleasing decoration. The 'Calverton' ware, made about the same time, was similar in its composition to the 'Avalon,' but quite different in decorative treatment, being turned upon the lathe, with spaces for bands, upon which were overlaid conventional relief ornaments, which produced a refined effect when treated with delicate colors and outlined with darker tints of gold."

In 1885 Parian wares were produced, with modelled flowers, panels, with beads in relief, medallions of Thorwaldsen's "Seasons," and similar works. During the greater part of this time the Chesapeake Pottery was also making a varied line of toilet ware, in a fine ivory body. The so-called "Roman" set, which had an embossed surface with an ornamentation of grape leaves, was one of the first produced. In 1886, the manufacture of the fine semi-porcelain was commenced, and the "Arundel" dinner service was put upon the market, the first work of the kind designed by Mr. Haynes, which has since been extensively copied by American, English and German potters and sent to this country for sale in china and cheaper grades of ware.

The latest line of the Chesapeake Pottery is a line of parlor and banquet lamps, clocks and large decorative vases, all characterized by originality of design, grace of form and delicacy of execution. This now forms the main line of goods produced at the factory. Mr. Haynes has also recently worked out a strong design for a water filter of large proportions, one of the decorations being an effective all-over pattern made up of the fleur-de-lis and a quartered rosette, employed alternately, applied in deep underglaze blue.

The Edwin Bennett Pottery, which began on a small scale was the first to be established south of what was known as the Mason and Dixon line, for making the finer grades of ware. About two years after starting, Mr. Bennett admitted his brother William to partnership, and the firm became E. & W. Bennett and so continued until the

FIG. 1.—CHESAPEAKE POTTERY WORKS, D. F. HAYNES AND SON, BALTIMORE.

FIG. 2.—MARYLAND POTTERY WORKS, EDWIN BENNETT COMPANY, BALTIMORE.

spring of 1856 at which time the latter retired from active business on account of failing health. During this period silver and gold medals were awarded the firm by the Maryland Institute for "superiority of Queensware," the exhibits consisting of yellow and Rockingham, sage and blue-colored hard-body wares, such as coffee-pots, pitchers, water-urns, vases, etc. Since 1856, Mr. Edwin Bennett has carried on the business alone. In 1869 he enlarged the factory and more than doubled the output, and the manufacture of white ware was commenced. Shortly afterwards a decorating department was added. Mr. Bennett originated and first made the "Rebekah" teapot in 1851 in Rockingham ware and has continued its manufacture to this day, the demand for it being regular and constant. A few years ago Mr. Bennett devoted some attention to the production of Parian and Belleek wares. A small quantity of the egg-shell china was made in 1886 of excellent quality in tea sets, but as its manufacture would have interfered with the general business of the works, it was discontinued.

In 1890 Mr. Bennett changed his business into a corporation entitled The Edwin Bennett Pottery Company. With Mr. Henry Brunt as manager they commenced the manufacture of high-grade dinner, tea, and toilet ware in American porcelain. Especially worthy of mention are their underglaze decorations in old blue and gold. Another specialty is the manufacture of jardinieres in colored glazes. These they make in a variety of forms, with ornamentation in relief.

The trade-mark is a globe, showing the western hemisphere, with a sword driven through the United States. The guard of the sword carries the initial of the company, while underneath is their motto. More recently Mr. Bennett has also gone into the manufacture of sanitary ware and has purchased the works of the Maryland Pottery Company.

The factory of the M. Perrine and Son's at 1009 W. Baltimore Street, is perhaps one of the oldest in the State, having been established in 1827. The product at first was stoneware and earthenware, but in more recent years the stoneware branch of the industry

was given up, and Rockingham and yellow ware added. The clays are obtained in large part from near Locust Point and Spring Gardens, and come chiefly from the Columbia formation. At present the earthenware output is chiefly flower-pots and flue tops. The flower-pots are molded on a jig-wheel over 6 inches in diameter, but sizes under this are formed in a press. For very large ones turning by hand on a potter's wheel is found preferable. The yellow and Rockingham wares include the usual forms of domestic articles.

Yellow, Rockingham, and earthenware are also made at the factory of H. J. Schmidt, 301 Frederick Avenue. The clays employed are obtained in the vicinity of Baltimore in part from the Arundel formation.

At Catonsville flower-pots are made at the factory of George S. Kalb and Son, the clay used being a residual peridotite clay obtained a few miles northeast of the factory.

Other potteries making earthenware are located at Cumberland, Hagerstown, and Frederick.

BIBLIOGRAPHY.

In the following Bibliography no attempt is made at completeness, it being intended simply to give the titles of the more important and accessible works relating to the technology of clay and the occurrence of clay in different localities in the United States. Any one desiring a more detailed list of titles can easily find it by consulting the Bibliography by Branner, referred to below. Those marked "b" treat of the technology of clay; "a," are purely geological.

BAIN, H. F. Clay Ballast—Its Method of Manufacture and Cost.
Mineral Industry, vol. vi, New York, 1898, pp. 157-160.

——— Geology of Plymouth County.
Iowa Geological Survey, vol. viii, Des Moines, 1898, pp. 351-354.

——— The Manufacture of Paving-brick in the Middle West.
Mineral Industry, vol. vii, New York, 1899.

BARBER, EDWIN A. The Pottery and Porcelain of the United States.
G. P. Putnam's Sons, New York, 1893, 433 pp.

BINNS, C. F. Ceramic technology (b).
2nd Edit., London, 1898, 214 pp.

BISCHOF, C. Die Feuerfesten Thone (b).
2nd Edit., viii, 462 pp., 90 figs., 2 pls., Leipzig, 1895.

BLATCHLEY, W. S. A preliminary report on the clays and clay industries of the coal-bearing counties of Indiana.
Ind. Dept. of Geology and Natural Resources, 20th Ann. Rept., Indianapolis, 1896, pp. 24-185.

——— The clays and clay industries of northwestern Indiana.
Ind. Dept. of Geology and Natural Resources, 22nd Ann. Rept., Indianapolis, 1898, pp. 105-154.

BLUE, A. Vitrified Brick for Pavements (b).
Ontario Bureau of Mines, 3rd Ann. Rept., Toronto, 1893, pp. 103-132.

BOCK, O. Die Ziegel fabrikation, Ein Handbuch.
9th Edit., 353 pp., Leipzig, 1901.

BRANNER, J. C. Bibliography of Clays and the Ceramic Arts.
Bull. U. S. Geol. Survey, No. 143, Washington, 1896, 114 pp.

BUCKLEY, ERNEST ROBERTSON. The Clays and Clay Industries of Wisconsin.
Wis. Geol. and Nat. Hist. Survey, Bull. No. VII, (Pt. 1), Economic Ser. No. 4, Madison, 1901.

CHAMBERLAIN, T. C. Geology of Eastern Wisconsin (a).
Geol. of Wis., Final Rept., vol. ii, pt. ii, Madison, 1877, pp. 235-239.

——— Building Material—Clays (a).
Geol. of Wis., Final Rept., vol. i, pt. iii, ch. iv., Madison, 1883, pp. 668-673.

COOK, GEORGE H. Report on the Clay Deposits of Woodbridge, South Amboy, and other Places in New Jersey, together with their use for Fire-Brick, Pottery, etc. (a).
Geol. Survey of N. J., Trenton, 1878, 381 pp.

COOK, R. A. The Manufacture of Fire-Brick at Mount Savage, Maryland.
Trans. Amer. Inst. Min. Eng., vol. xiv, New York, 1886, pp. 698-706.

COX, E. T. Porcelain, Tile and Potter's Clays (a).
8th, 9th and 10th Ann. Repts. Geol. Survey of Ind., Indianapolis, 1879, pp. 154-161.

CRARY, J. W., SR. Brickmaking and Brickburning, or Sixty years a brickmaker. A Practical Treatise on brickmaking and burning.
Indianapolis, 1890.

CRAWFORD, J. J. Structural Materials—Clays, Bricks, Pottery, etc.
Cal. State Min. Bureau, 13th Rept., Sacramento, 1896, pp. 612-620.

DAVIS, CHARLES T. A Practical Treatise on the Manufacture of Bricks, Tiles, Terra Cotta, etc. (b).
2nd Edit., Philadelphia, 1889, 501 pp.

DÜMMLER, K. Die Ziegel und Thonwaaren Industrie in den Vereinigten Staaten und auf der Columbus-Welt-ausstellung in Chicago 1893.
Aus Deutsch Töpfer u. Ziegler-Zeit., Halle, 1894, 180 pp.

——— Handbuch der Ziegel-Fabrikation (b).
Halle, 1897, 352 pp.

GRIFFIN, H. H. Clay Glazes and Enamels (b).
Indianapolis, 1896, 138 pp.

HILL, R. T. Clay Materials of the United States (a).
Min. Resources of U. S., 1891, U. S. Geol. Survey, Washington, 1893, pp. 474-528.

HOFMAN, H. O. Further Experiments for Determining the Fusibility of Fire-Clays.
Trans. Amer. Inst. Min. Eng., vol. xxv, New York, 1896, pp. 3-17.

——— A Modification of Bischof's Method for Determining the Fusibility of Clays, as Applied to Non-Refractory Clays, and the Resistance of Fire-Clays to Fluxes.
Trans. Amer. Inst. Min. Eng., vol. xxviii, New York, 1899, pp. 435-440.

——— and DEMOND, C. D. Some Experiments for Determining the Refractoriness of Fire-Clays (b).
Trans. Amer Inst. Min. Eng., vol. xxiv, New York, 1895, pp. 42-66.

——— and STOUGHTON, B. Does the Size of Particles have any Influence in Determining the Resistance of Fire-Clays to Heat and to Fluxes?
Trans. Amer. Inst. Min. Eng., vol. xxviii, New York, 1899, pp. 440-444.

HOLMES, J. A. Notes on the Kaolin- and Clay-Deposits of North Carolina (a).

Trans. Amer. Inst. Min. Eng., vol. xxv, New York, 1896, pp. 929-936.

HOPKINS, THOMAS C. Clays and Clay Industries of Pennsylvania. I. Clays of Western Pennsylvania (In Part) (a).

Appendix to Ann. Rept. of Pa. State College for 1897. State College (?), 1898, 183 pp., 5 pls.

IRELAN, L. Pottery.

Cal. State Min. Bureau, 9th Ann. Rept., Sacramento, 1890, pp. 240-261, 3 pls.

JERVIS, W. P. An Encyclopedia of Ceramics.

Crockery and Glassware Journal, 1898-1899.

JONES, CLEMENS C. A Geologic and Economic Survey of the Clay-Deposits of the Lower Hudson River Valley.

Trans. Amer. Inst. Min. Eng., vol. xxix, New York, 1899, pp. 40-83.

LADD, GEORGE E. A Preliminary Report on a part of the Clays of Georgia.

Geol. Survey of Ga., Bull. No. 6-A, Atlanta, 1898, 199 pp. 17 pls.

——— Notes on the Cretaceous and Associated Clays of Middle Georgia.

Amer. Geol., vol. xxiii, Minneapolis, 1899, pp. 240-249.

———Clay, Stone, Lime and Sand Industries of St. Louis City and County.

Geol. Survey, Missouri, Bull. No. 3, Jefferson City, 1890, pp. 5-83, 3 pls., 2 maps.

LANGENBECK, K. Chemistry of Pottery (b).

Chemical Pub. Co., Easton, 1896, 197 pp.

LESLEY, J. P. Some general considerations respecting the origin and distribution of the Delaware and Chester Kaolin deposits (a).

Ann. Rept. Geol. Survey Pa. for 1895, Harrisburg, 1896, pp. 571-614.

LOUGHRIDGE, R. H. Report on the Geological and Economic Features of the Jackson Purchase Region (a).

Geol. Survey Ky., Frankfort, F 1888, pp. 84-118.

McCALLEY, HENRY. Report on the Valley Regions of Alabama (Paleozoic Strata): Clays. In two parts, I. The Tennessee Valley Region.

Geol. Survey Ala., Montgomery, 1896, p. 68.

——— Ibid. II. The Coosa Valley Region.
Geol. Survey Ala., Montgomery, 1897, pp. 84-86.

MEADE, D. W. Manufacture of Paving-Brick (b).
Trans. Amer. Soc. Civ. Eng., vol. xxiv, 1893, p. 552.

MONTGOMERY, H. G. Manufacture of Glazed Brick.
London, 1894.

ORTON, E., JR. The Clay-Working Industries of Ohio (b).
Ohio Geol. Survey, vol. vii, pt. 1, Norwalk, 1893, pp. 69-254.

PENNOCK, J. D. Laboratory Note on the Heat-Conductivity, Expansion and Fusibility of Fire-Brick.
Trans. Amer. Inst. Min. Eng., vol. xxvi, New York, 1897, pp. 263-269.

PERIODICALS.

Brick (monthly). Chicago, Ill.
Brickbuilder (monthly). Boston, Mass.
Brick-maker (bi-weekly). Chicago, Ill.
Clay (quarterly). Willoughby, O.
Clay Worker (monthly). Indianapolis, Ind.
Crockery and Glassware Journal (weekly). New York City.
Paving and Municipal Engineering (monthly). Indianapolis, Ind.
Thonindustrie Zeitung. Berlin, Germany.
Töpfer und Ziegel Zeitung. Berlin, Germany.

PLATT, F. Fire-Brick Tests.
Second Geol. Survey, Pa., 1876-1878, vol. MM, Harrisburg, 1879, pp. 270-279.

——— Clays of the Hudson River Valley.
10th Ann. Rept. N. Y. State Geologist, New York, 1890.

RIES, HEINRICH. Clay.
Mineral Industry, vol. ii, New York, 1894, pp. 165-210.

——— Technology of the Clay Industry (b).
16th Ann. Rept. U. S. Geol. Survey, pt. iv, 1892-1895, Washington, 1895, pp. 523-575.

——— The Pottery Industry of the United States (b).
17th Ann. Rept. U. S. Geol. Survey, pt. iii (cont.), 1895-1896, Washington, 1896, pp. 842-880, 2 pls.

——— Clay Deposits and Clay Industry in North Carolina. A Preliminary Report.
N. C. Geol. Survey, Bull. No. 13, Raleigh, 1897, 157 pp.

———— The Clay-Working Industry in 1896.
18th Ann. Rept. U. S. Geol. Survey, pt. v (cont.), 1896-1897, Washington, 1897, pp. 1105-1168.

———— The Kaolin and Fire-Clays of Europe.
19th Ann. Rept. U. S. Geol. Survey, pt. vi (cont.), 1897-1898, Washington, 1898, pp. 377-468.

———— The Ultimate and Rational Analysis of Clays and Their Relative Advantages.
Trans. Amer. Inst. Min. Eng., vol. xxviii, New York, 1899, pp. 160-166.

———— Preliminary Report on the Clays of Alabama (a).
Geol. Survey of Ala., Bull. No. 6, Jacksonville, Fla., 1900, 220 pp.

———— Clay Industries of New York.
N. Y. State Museum, Bull. No. 35, New York, 1900, 944 pp.

Seger, H. Gesammelte Schriften.
Berlin.

Societies.—Transactions of the American Ceramic Society, Columbus, O.

Smock, J. C. The Fire-Clays and associated Plastic Clays, Kaolin, Feldspars, and Fire-Sands of New Jersey (a).
Trans. Amer. Inst. Min. Eng. vol. vi, New York, 1879, pp. 177-192.

Spencer, J. W. Clays and Brick Pavements (a).
Geol. Survey of Ga., The Paleozoic Group, Atlanta, 1893, pp. 276-288.

Struthers, J. The Thermoelectric Pyrometer of M. le Chatelier.
School of Mines Quart., vol. xii, New York, 1891, pp. 143-157; vol. xiii, 1892, pp. 221-222.

Wheeler, H. A. A Calculation of the Fusibility of Clays.
Eng. and Min. Jour., vol. lvii, New York, 1894, pp. 224-225.

———— Vitrified Paving-Brick.
Published by Clay Worker, Indianapolis, 1895.

———— Clay Deposits.
Missouri Geol. Survey, vol. xi, Jefferson City, 1896, 622 pp., 38 pls.

Zwick, O. Die Natur die Ziegelthone und die Ziegel-fabrikation der Gegenward.
A. Hartlebek, Vienna, Buda Pesth, Leipsig, 2nd edit., 1894, 544 pp.

TABLE SHOWING THE BEHAVIOR OF A NUMBER OF MARYLAND CLAYS HEATED TO CONE 27.

No.	Locality.	Sheet.	Geol. Age.	Behavior.	Remarks.
	ALLEGANY COUNTY.				
	Mt. Savage......	Frostburg 1.....	Pottsville ..	Incipient fusion.	Flint-clay.
	Mt. Savage......	" 1.....	" ..	Barely incipient fusion.	Shale.
	ANNE ARUNDEL CO.				
238..	Severn River, Baldwin	Relay 8......	Raritan	Nearly vitrified..	White clay.
246..	Severn River, Brown........	" 9........	"	Viscous.	Yellowish white clay.
8852..	Earleigh Heights.	......	"	Vitrified........	......
8960..	Deep Run.......	Relay 1	Patuxent...	Nearly incipient fusion	......
	Dorsey Estate...	" 8.........	Raritan	Vitrified........	Clay.
8862..	Harwood.... ...		Residual ...	Vitrified.... ...	......
8843..	Wade Estate	" 5.........	Raritan	Not quite vitrified	......
	BALTIMORE CO.				
8816..	Baltimore.......	Baltimore 7.....	Patapsco. ..	Vitrified........	......
254..	1½ mi. S. E. Mt. Winans.	" 8.....	" ...	Vitrified........	......
	CECIL COUNTY.				
14..	Atkinson Cut....	Elkton 4.......	Residual....	Incipient fusion.	Crude kaolin.
245..	Carpenter Point..	Havre de Grace 9.	Patapsco. ..	Viscous.	Stoneware clay.
240..	Eder............	Elkton 4.......	" ...	Nearly viscous..	......
288..	Eder............	" 4.......	" ...	Partly vitrified..	......
292..	Eder............	" 4.......	" ...	" " ..	......
5795..	Elk Neck........	"	Raritan	Viscous.	......
5817..	Gray's Hill......	" 6.......	Patapsco. ..	Vitrified........	......
263..	Leslie...........	" 4.......	Residual ...	Incipient fusion.	Viscous 30.
5801..	Mckinneytown ..	"	Raritan	Nearly vitrified..	......
256..	Northeast.	" 4.......	Patapsco. ..	Vitrified........	......
258..	Maryl'd Clay Co..	" 4.......	Residual ...	Vitrified........	Washed clay.
253..	Northeast River.	" 7.......	Patapsco. ..	Vitrified........	......
264..	Northeast.......	" 4.......	" ...	Vitrified at 30...	......
5796..	Northeast.......	" 4.......	" ...	Vitrified........	......
97..	Jackson.........	Havre de Grace 9.	Residual ...	Incipient fusion.	......
	GARRETT COUNTY.				
	Blaine..........	......	Residual ...	Incipient fusion.	Flint-clay.
	Blaine..........	......	" ...	" "	Shale.
	Swallow Falls...	......	Pottsville ..	Incipient fusion.	Flint-clay.
	Swallow Falls...	......	" ..	Nearly incipient fusion.	Shale.
	HARFORD COUNTY.				
	Sewall.	......	Patuxent...	Viscous.	White micaceous clay.
	Bush River... ..	......	Patapsco. ..	Incip. fusion....	......
	HOWARD COUNTY.				
	Dorsey	Relay 1.........	Residual ...	Incipient fusion.	Used for fire-brick.
	Dorsey	" 1.........	Arundel....	Viscous.......	......
	PRINCE GEORGE'S COUNTY.				
3836..	Branchville......	E. Wash. 1......	Residual ...	Incipient fusion.	......
5857..	Branchville......	"	Patapsco. ..	Vitrified........	......
	Horsepen Run...		Raritan	Vitrified........	......

TABLE SHOWING RESULTS OF PHYSICAL TESTS ON MARYLAND CLAYS.

No.	Locality.	Sheet.	Age.	Rate of slaking.	Tempering. % water req.	Shrinkage. Air.	Shrinkage. Fire.	Total.	Tensile strength.	Incip. fusion.	Vitrification.	Viscosity.	Plasticity.
	ALLEGANY COUNTY.												
282	Savage Mountain	Frostburg	Mauch Chunk	Slow	19%	4	5	9	55	01	4	7	Lean
284	Near Franklin	"	Allegheny	"	16	3	5	8	40	1	5-6		"
	ANNE ARUNDEL COUNTY.												
248	Bodkin Point	North Point 4	Pleistocene	"	30	6	4	10	40	8	27+		Good
300	1 mile S. Bodkin Point	" "	"	"	35	8	10	18	160-180	1	4	7-8	"
266	2 miles S. Bodkin Point	" "	"	Mod. fast	40	11	9	20	223-250	05	2	7	Very good
175	Harman, ½ mile S.	Relay 4	Raritan	" "	19	4	6	10	60-70	3	8+		Moderate
257	F. Link's Pit	Baltimore 8	Arundel	" "	22½	6	9	15	77	1	6	10	Good
246	Severn River, Brown's.	Relay 9	Raritan	Slow	24	6	10	16	Low	1-2	10	27	Moderate
247	Glass Sand Pits	"	"	Fast	17	5	11	16	90	3	8	10+	Good
	BALTIMORE COUNTY.	Baltimore 8	Arundel	Slow	30	7	11	18	134	1	6	8+	"
	Rittenhouse, Baltimore	" 8	Patapsco	Mod. fast	31	9	11	20	111	05	4	7-8	"
250	Curtis Bay Junction	" 8	Arundel	" "	26½	5	7	12	75	2	8	10+	"
232	Locust Point	" 8	"	Slow	22	5	7	12	65-70*	6	10	27–	Very good
	CECIL COUNTY.												
239	Bull Mountain	Elkton 7	Pleistocene	"	25	5	5	10	123-134	01	5	7+	Good
245	Carpenter Point	Havre de Grace 9	Patapsco	"	33	6	6	12	110-125	1	8	25	Very good
240	Eder	Elkton 4	"	"		6	8	14	68-75	4	10+	27+	" "
234	Grosh stoneware clay	" 5	"	"	23	6	10	16	110-125	01	8	12-14	" "
263	Leslie	" 4	Residual	Fast	20	2	2	4	10	27			Lean
251	Northeast		"	"	18	1½	12½	14*	20	10	27		Lean
253	Northeast River	" 7	Patapsco	Slow	30	6	4	10	40	8	27+		Moderate
260	Shannon Hill	"	"	Mod. fast	20	5	3½	8½	100	3	8	10+	Fair
	HOWARD COUNTY.												
262	Dorsey	Relay 1	Residual	Fast	25	4	5†	....	15	27+			Lean
233	"	"	Arundel	"	22	5	7	12	60		12	27	Good
	PRINCE GEORGE'S COUNTY.												
270	Upper Marlboro	E. Washington 9	Eocene	"	35	9	11	20	132	05	6	10	Fair

* At cone 10.

† At cone 8.

ANALYSIS OF MARYLAND CLAYS.

No.	Locality.	Remarks.	Geol. Age.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Alk.	Ignition.	Total.	Total Fluxes
	ALLEGANY COUNTY:											
271	Cumberland	Bottom shale for paving brick	Jennings	70.25	17.71	4.10	.70	.40	1.76	4.80	99.72	6.96
272	Cumberland	Top shale for paving brick	Jennings	68.30	17.50	4.00	.80	.65	3.10	5.10	99.45	8.55
275	Frostburg	Not worked	Conemaugh.	51.05	28.60	3.75	3.80	1.24	.50	10.85	99.79	9.29
281	North of Westernport	Not worked	Allegheny	56.50	22.90	6.37	1.60	1.58	1.60	10.00	99.55	11.15
...	Mount Savage	Flint clay	Pottsville	56.15	33.295	.59	.17	.115	....	9.68	100.00	.875
	ANNE ARUNDEL COUNTY:											
238	Severn River	Baldwin's sand pit, not worked	Raritan	75.40	16.73	1.27	.35	.90	.50	5.30	100.45	3.02
298	Bodkin Point	Not worked	Pleistocene.	69.40	19.70	2.00	.20	.60	.62	7.85	100.37	3.42
...	Dorsey Estate, Severn River	Not worked	Raritan	70.08	23.00	.96	....	....	....	5.96	100.00	.96
265	Swan Cove, Magothy River.	Not worked	Raritan	58.00	19.10	2.80	.93	.08	.80	18.20	a99.91	4.61
266	Shore below Bodkin Point.	Vivianite clay, not worked	Pleistocene.	58.10	26.00	3.90	.90	.35	.60	2.40	99.25	5.75
	BALTIMORE COUNTY:											
243	Baltimore	Sewer-pipe clay	Arundel	59.70	27.00	2.10	.60	.52	1.96	8.20	100.08	5.18
250	Curtis Bay, Baltimore	Brick clay	Arundel	71.55	17.70	2.25	.60	.86	.42	6.50	99.88	4.13
257	F. Link's Pit, S. of Balto.	Terra cotta clay	Arundel	68.30	21.27	1.43	.52	.80	.20	7.55	100.07	2.95
...	Cromwell Bros. Brick Yard, E. of Baltimore	Sandy red clay, 8 ft. from top	....	77.62	12.46	4.10	.52	.46	....	4.58	100.74	5.08
...	Cromwell Bros. Brick Yard, E. of Baltimore	Less sandy gray clay, 22 ft. from top	....	72.02	16.66	1.38	.12	.85	....	6.35	97.38	2.35
...	Cromwell Bros. Brick Yard, E. of Baltimore	Clean blue clay, 38 ft. from top.	....	71.66	16.92	1.82	....	.93	....	6.14	97.47	2.75
	CECIL COUNTY:											
234	Bacon Hill	Grosh stoneware clay	Patapsco	65.70	20.30	1.00	3.50	1.44	.62	7.60	100.16	6.56
245	Carpenter Point	Stoneware clay	Patapsco	72.50	17.00	1.50	.35	.60	1.10	6.50	99.45	3.55
239	Bull Mountain	Not worked	Pleistocene.	76.80	15.00	2.50	.20	.41	.62	5.15	100.68	3.73
251	Northeast	Kaolin	Algonkian.	55.65	30.53	.97	.75	.60	.20	12.30	100.85	2.52
	GARRETT COUNTY:											
...	Blaine	Flint clay, unworked	Pottsville	45.40	38.90	1.01	.31	tr.	tr.	15.20	100.82	1.32
...	Swallow Falls	Flint clay	Pottsville	61.00	26.36	.83	.21	.10	tr.	11.60	100.04	1.14
...	Swallow Falls	Shale fire-clay	Pottsville	46.10	38.05	1.05	.39	.60	....	12.95	99.14	2.04
	PRINCE GEORGE'S COUNTY:											
270	Upper Marlboro	Not worked	Eocene	58.60	28.71	8.22	.40	.85	.63	8.90	100.81	4.60
	WASHINGTON COUNTY:											
...	Williamsport	Dark red brick clay	Pleistocene.	67.50	17.20	6.70	.45	....	1.76	5.90	99.51	8.91
...	Williamsport	Light gray brick clay	Pleistocene.	61.30	22.30	3.80	.70	....	2.10	8.00	98.20	6.60

a P_2O_5 undetermined.

Directory of Maryland Clay Workers.

POTTERY.

NAME.	OFFICE.	WORKS.
Edwin Bennett Roofing Tile Co	Eden and Aliceanna Sts., Baltimore	Baltimore.
Edwin Bennett Pottery Co	1301 Canton St., Baltimore	"
Maryland Pottery Co	President and Fawn Sts., Baltimore	"
Samuel Ales	1412 Eastern Av., Baltimore	"
Chesapeake Pottery Company, D. F. Haynes & Sons	Nicholson and Decatur Sts., Baltimore	"
H. J. Schmidt	301 Frederick Av., Baltimore	"
M. Perine & Sons	1009 W. Baltimore St., Baltimore	"
George S. Kalb & Son	Catonsville	Catonsville.
Eichner Bros	Cumberland	Cumberland.
J. J. Nottugal & Son	327 W. Potomac St., Frederick	Frederick.
Martin Happel	Hagerstown	Hagerstown.

BRICK, TILE AND TERRA COTTA.

NAME.	OFFICE.	WORKS.
Harman & Judic Brick Company	Station E, Baltimore	Arlington.
Baltimore Brick Company	1001 Atlantic Trust Building, Baltimore	Baltimore.
E. Bennett Roofing Tile Works	Eden and Aliceanna Sts., Baltimore	"
Wm. W. Dashields & Son	313 Warren Av., Baltimore	"
Baltimore Terra Cotta Works, N. M. Rittenhouse, Prop	Jackson and Clement Sts., Baltimore	"
Cyrus W. Davis	Berlin	Berlin.
P. A. Bier	Bier	Bier.
Gilbert Moyers	Bladensburg	Bladensburg.
Raum Bros. Brick Company	Friendly	Broad Creek.
Potee Bros	Brooklyn (sub-station)	Brooklyn.
C. M. Wenner	Brunswick	Brunswick.
Jas. C. Leonard	Cambridge	Cambridge.
V. Lynn Rea	"	"
Michael Adams, Jr	17th St., Canton, Baltimore	Canton.
Chas. T. Neepier	Catonsville	Catonsville.
Ernest Perry	Centerville	Centerville.
Henry S. Barnett	Chestertown	Chestertown.
George M. Collins	Crisfield	Crisfield.
Queen City Brick & Tile Company	Cumberland	Cumberland.
Burns & Russell Company	6 South St., Baltimore	Dundalk.
Severn Brick Company, Perry H. Kashner, Prop	Earleigh Heights	Earleigh Heights.
Jos. H. White & Son	Easton	Easton.
John Gilpin Brick Company	Elkton	Elkton.
John M. Stouter	Emmitsburg	Emmitsburg.

NAME.	OFFICE.	WORKS.
Peter Brooky	Frederick	Frederick.
The Frederick Brick Works	"	"
Bilbrough Bros	Greensboro	Greensboro.
Alfred Henson	Hagerstown	Hagerstown.
James E. S. Pryor	"	"
Semler Brick Company	"	"
F. W. Wiebel	"	"
Jonas Winter, Agt. for Mrs. Barr	"	"
Washington Hydraulic-Pressed Brick Company	Washington, Kellogg Bldg.	Harman.
Edward Hubbert	Hynson	Hynson.
Solomon & Briley	Wilmington, Del.	Iron Hill.
Knight & Purgitt	Keyser, W. Va.	Keyser Junction.
A. B. Nitch Brick Company	301 Ramsay St., Baltimore	Lansdowne.
Mt. Savage Enameled Brick W'ks.	Mt. Savage	Mt. Savage.
Nichols & Still	Nichols	Nichols.
The Acme Red Brick & Fire Brick Company	Northeast	Northeast.
Maryland Clay Company	"	"
Rutland Fire Clay Company	Rutland, Vt.	"
Frank Debelius & Sons	Orangeville	Orangeville.
T. M. Bateman	Pinto	Pinto.
Hugh McMichael	Pocomoke City	Pocomoke City.
David S. Strayer	Ridgely	Ridgely.
Benj. D. Stephen	Riverdale	Riverdale.
Peter Jones	Robinson	Robinson.
Wallace Cornwall	Rockville	Rockville.
Champion Brick Company, Jacob Klein, President	Rosedale	Rosedale.
Salisbury Brick Company, Joseph & Mitchell, Props	Salisbury	Salisbury.
Hugh J. Phillips & Co	"	"
S. C. Todd & Co	"	"
W. S. Lewis	Snow Hill	Snow Hill.
Hope & Seth	St. Michaels	St. Michaels.
Calvert Brick Company	726 Equitable Building, Baltimore	Solomon.
R. G. S. Smith	Sunnyside	Sunnyside.
Peach Bottom Cement, Tile and Brick Company	200 N. Calvert St., Baltimore	Texas.
D. W. Zentz	Thurmont	Thurmont.
R. J. Smith	Roberts	Tilghman.
Enoch W. Wilson	Vienna	Vienna.
J. Graham Johnson	Walkersville	Walkersville.
Robert E. Frizzell	Westminster	Westminster.
Chas. L. Groft	"	"
Elias W. Oursler	"	"
Conococheague Brick & Earthenware Company	Williamsport	Williamsport.
Mitchell H. German	Delmar, Del	Wicomico County.

FIRE BRICK AND STOVE BRICK.

NAME.	OFFICE.	WORKS.
Baltimore Brick Company	1001 Atlantic Trust Bldg., Baltimore	Baltimore.
Baltimore Retort and Fire Brick Company	Hull and Nicholson Sts., Baltimore	"
Columbia Stove Brick Works, Jas. E. Wright, Prop	1345 Columbia Av., Baltimore	"
Baltimore Terra Cotta Works, N. M. Rittenhouse, Prop	Baltimore	"
Jas. Gardner & Son	Cumberland	Cumberland.
The Frederick Brick Works	Frederick	Frederick.
Savage Mountain Fire Brick W'ks	Frostburg	Frostburg.
Union Mining Company	Mt. Savage	Mt. Savage.
The Acme Red Brick & Fire Brick Company	Northeast.	Northeast.
Cecil Fire Brick Company	"	"
Green Hill Fire Brick Company	"	"
Wakefield Fire Brick Company	"	"
Salisbury Brick Company, Joseph & Mitchell, Props	Salisbury	Salisbury.

ADDENDA.[1]

Results of Practical Tests Made on Several Samples of Maryland Clay, made at the Works of the Onondaga Vitrified Brick Company of Warner's, N. Y.

While the examination of clay in the laboratory often gives many valuable clues regarding the possible applications of the material, still it is always of great value to be able to put a large sample of the clay through a practical test, for if the test is properly carried out and by a reliable firm the results will be at once appreciated by the practical man. In the course of the work on the Maryland clays several deposits were found which were being used either little or not at all and which on account of their easily accessible location seemed to possess considerable value provided the clay had the proper qualities. The laboratory tests were encouraging, and it was therefore decided to collect several large samples from several of these localities, send them to a brick works, where they could get a fair and thorough test in order to determine their fitness for the manufacture of several grades of clay products—such as paving brick, pressed brick, and vitrified brick—which should certainly find a good market in Maryland and neighboring states. The materials which were selected for these tests were:

A. A gray, sandy, Arundel clay from the hill south of Mt. Winans. This deposit is large and at least 30 feet in thickness.

B. A mixed red, yellow, and whitish clay underlying the preceding, and likewise forming a bed of considerable size.

C. A rich, blue plastic clay taken from the shore of Chesapeake Bay, south of Bodkin Point, and occurring in the first bluff north of the neck connecting Gibson Island with the mainland on the Cook farm. This clay contains numerous specks of vivianite.

D. A yellowish clay from the north end of the same bluff as the blue vivianite clay.

[1] These tests, which were made after the foregoing report was in press, are believed to be of so much interest to the clay interests of the State that they have been appended to the report. Additional details regarding the localities may be found on pages 350, 386–390.

In making the tests the following lots were used: First, a mass composed entirely of clay A; second, a mixture composed wholly of clay B, or mixed with some mottled red, yellow and white; third, a mixture of 50 per cent each of A and B; fourth, clay D alone; fifth, a mass composed wholly of C; sixth a mixture composed of equal parts of C and D; and seventh, a mixture of equal parts of A, B, C, and D.

The tests were carried out with a view of determining their adaptability to the manufacture of common, vitrified, front, and also hollow brick.

Method of Manufacture.—One of these clays, the vivianite clay, was sufficiently hard to require breaking up in the disintegrator before tempering. The tempering was done in a pug-mill and the addition of sufficient water to make the clay plastic enough for molding by the stiff-mud process on an auger machine. The drying of the wares was done in a radiated-heat tunnel-drier, the bricks being piled on cars. The burning was carried out in a circular down-draft kiln.

The hollow bricks were subjected to the same treatment and heat as the common bricks, but the method of molding differed, in that they were molded on a plunger stiff-mud machine instead of on an auger machine.

The vitrified bricks were burned at cone 3.

The size of the opening in the dies in the case of the bricks was $8 \times 3\frac{3}{4} \times 2\frac{3}{8}$ inches, while in the case of the hollow brick the die opening was $3\frac{3}{4} \times 2\frac{3}{8}$ and the brick was cut off $8\frac{1}{2}$ inches long. The following are the details of the different tests:

Mixture No. 1.—The sandy, gray, Arundel clay from south of Mt. Winans. This worked up easily in the pug-mill and stood the drying well, but required strong firing. It burned to a buff color and the product had a very good texture and structure. The material worked very easily and without doubt will make a very good fireproofing in all sizes but might not be found as well adapted for the manufacture of porous terra cotta which usually requires a very plastic clay. The clay, however, works much better than one would imagine from an examination of the green material. The size of the burned brick was as follows: common brick $7\frac{3}{4}'' \times 3\frac{5}{8}'' \times 2\frac{7}{32}''$, hard brick $7\frac{5}{8}'' \times 3\frac{9}{16}'' \times 2\frac{3}{16}''$, hollow brick, $7\frac{15}{16}'' \times 3\frac{9}{16}'' \times 2\frac{5}{16}''$.

This clay alone would require higher temperature for vitrifying than is usually reached in the paving-brick manufacture.

Mixture No. 2.—This did not pug as easily as the preceding, but with thorough mixing made an excellent common brick. It will not stand rapid drying or strong burning and the brick on account of the high plasticity of the mottled clay is inclined to laminate somewhat. It makes a very good hollow brick in the dimensions given below, but if large size blocks were made there might be some danger from warping, and in order to get vitrification a rather high shrinkage takes place. The size of the burned common brick was $7\frac{3}{8}''$ x $3\frac{7}{16}''$ x $2\frac{1}{16}''$, the size of the vitrified brick $7\frac{5}{16}''$ x $3\frac{3}{8}''$ x $2\frac{1}{16}''$, and of the hollow brick, $7\frac{1}{16}''$ x $3\frac{3}{8}''$ x $2\frac{1}{8}''$. The color of the burned brick is red with very fine black specks. The texture is very dense and the brick is strong and when vitrified the color is brown.

Mixture No. 3.—This requires thorough mixing but stands the dryer well and in burning stands severe firing with little danger of injury, which is a very desirable point. The clay works well in the machine and shows only slight laminations. It burns to an excellent red color, under normal firing but when vitrified the color is brown. The burned common brick was $7\frac{1}{2}''$ x $3\frac{1}{2}''$ x $2\frac{1}{8}''$, the vitrified brick, $7\frac{3}{8}''$ x $3\frac{3}{8}''$ x $2\frac{1}{16}''$.

Mixture No. 4.—Composed of the yellow clay D. This is very easily pugged although it contains some small yellow stones which, however, would not be any detriment in making ordinary brick. This possesses several very desirable qualities, namely, *it works well in the auger machine, stands rapid firing,* and *drying,* and *burns to a strong, dense body* of a *beautiful red color,* and consequently it would make a *fine red front brick.* For paving-brick the pebbles would have to be screened out or crushed, preferably the latter, for screening involves preliminary drying. This clay does not make as good hollow brick as the other clays although the smaller sizes could be made without much trouble. It vitrifies somewhat above cone 3. The sizes of the burned brick were as follows: common brick, $7\frac{1}{2}''$ x $3\frac{1}{2}''$ x $2\frac{1}{8}''$; vitrified brick, $7\frac{3}{8}''$ x $3\frac{7}{16}''$ x $2\frac{1}{8}''$; hollow brick, $7\frac{5}{8}''$ x $3\frac{1}{2}''$ x $2\frac{1}{4}''$.

Mixture No. 5.—This was composed entirely of the vivianite clay, marked C. The material was broken up in the disintegrator before

being put into the pug-mill. It works very smoothly in both the auger and the plunger stiff-mud machines but has to be handled with some care in the drying and in the kilns. The material when used by itself shrinks rather much for the successful manufacture of a vitrified brick but a good sharp sand would very much add to its value for all purposes except hollow brick. Deposits of sand are not at all uncommon along the shores of the Chesapeake Bay so that no doubt some material could readily be found to mix in with it. In small sized products it would work very well alone, although even here it must be dried slowly. When normally burned it produced a good red color, when vitrified the color becomes a deep brown. The sizes of the burned brick were as follows: common brick $7\frac{3}{8}'' \times 3\frac{7}{16}'' \times 2\frac{1}{16}''$; vitrified brick, $7\frac{3}{16}'' \times 3\frac{3}{8}'' \times 2\frac{3}{16}''$.

Mixture No. 6.—Composed of equal parts of the vivianite and the yellow clay. This burns red when normally fired, and brown when vitrified and gives a very *strong* and *dense brick* with but *very slight lamination* which *stands the drying and the firing well.*

The shrinkage is a little heavy perhaps so that no doubt better results will be obtained by using a larger proportion of C in the mixture. The common brick when burned were $7\frac{5}{16}'' \times 3\frac{7}{16}'' \times 2\frac{1}{16}''$, the vitrified brick, $7\frac{1}{4}'' \times 3\frac{5}{16}'' \times 2$.

Mixture No. 7.—This contains equal parts of the four clays and gives a dense strong brick of fairly good red color. This mixture is considered by Mr. Naugle as giving promise of a very good paving mixture although it vitrifies above cone 3.

The Bolivar Fire-clay from Garrett County.

An outcrop of a flint fire-clay which apparently belongs at the horizon of the Bolivar fire-clay of Pennsylvania or a short distance below the Upper Freeport coal was seen in the bank of the North Fork of the Castleman river about 9/10 of a mile above the mouth of Tarkill Run. The flint which occurred as a massive ledge outcropping on the hillside had a thickness of about $3\frac{1}{2}$ feet with both top and bottom concealed. The real thickness is evidently more than this and may be several times as great.

Samples collected by Dr. G. C. Martin were submitted to the writer for examination.

The material is a flint clay which in general appearance is not unlike clays of that character, being hard and dense, and having conchoidal fracture. The chemical analysis of the material is as follows:

ANALYSIS OF FLINT CLAY, CASTLEMAN RIVER, GARRETT COUNTY.

Silica	51.881
Alumina	36.461
Ferric oxide	1.01
Lime	.98
Magnesia	.10
Alkalies	trace
Total	100.932

Being a flint clay it naturally has practically no plasticity when ground and mixed with water, and consequently its tensile strength is also exceedingly low, showing that it would have to be mixed with a plastic fire-clay in making it into fire-bricks. The refractoriness of the clay is, however, the most important item, and it was found on testing it that the fusion point of the clay is very nearly that of cone 35 of the Seger series, whose fusion point is about 3326° F. This makes the clay from Castleman river, one of the most refractory clays found in the United States.

For comparison with this it is interesting to note an analysis of similar material from Westmoreland county, Pennsylvania,[1] which is as follows:

ANALYSIS OF FLINT CLAY FROM WESTMORELAND COUNTY, PENNSYLVANIA.

Silica	51.92
Alumina	31.64
Ferrous oxide	1.134
Lime	.03
Magnesia	.443
Alkalies	.402
Water	13.49
TiO_2	1.16
Total	100.619

[1] Penn. Geol. Surv., MM, p. 258, Analysis No. 957, Kier Bros.

Another analysis from the same pit gave:

Silica	47.25
Alumina	34.35
Ferrous oxide	.693
Lime	.58
Magnesia	.09
Carbonic acid	.455
Alkalies	.261
TiO_2	1.99
Water	13.65
Total	99.319

As may be seen, these three analyses resemble each other in a general way but there may be variations even in the same pit, so that identity of composition is not necessarily required to give similarity in refractory behavior. Some of the other occurrences in Pennsylvania run as low as 9 or even 7 per cent of combined water.

INDEX

C

I